JUN 7 1918

Engineering Library

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CV.—No. 2733.] *LONDON: FRIDAY, MAY 17, 1918.* [*Registered at the General Post Office as a Newspaper.*] [PRICE..9d. BY INLAND POST ... 11d.

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See page 105, May 10. 6455

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See Advertisement page 121, May 10th.

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See Advertisement page 83.

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See Advertisement page 26. 6462

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See Advertisement page 48, May 10. 2402

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See Full Page Advt. page 58, May 3.

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6195
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See Full Page Advertisement May 3.

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TO ENGINEERS, CHEMICAL MANUFACTURERS AND FIRMS INTERESTED IN THE ELECTROLYTIC DEPOSITION OF COPPER.

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APPOINTMENTS OPEN.

The Admiralty are open to receive applications from gentlemen for Commissions as Lieutenants in the ROYAL MARINE ENGINEERS.
This Branch of the Royal Marine Corps has been formed with a view to the rapid execution of Civil Engineering and Constructional Works.
Candidates should have previous practical experience on Civil Engineering Works and be capable of setting out work and controlling men.
Candidates up to 50 years of age will be considered, but those under 35 should be in a lower Medical Category than Grade 1.
Pay and Allowances will be at the rates authorised for the Royal Engineers, and the usual Outfit Allowance will be granted.
Applications, with copies of testimonials and particulars of experience, should be addressed to the Civil Engineer-in-Chief, Admiralty, S.W. 1.
The top left-hand corner of the envelope to be marked "O.P. 1." L 413

RADCLIFFE EDUCATION COMMITTEE.

The Committee are prepared to receive

Applications for the Post of PRINCIPAL of the Technical School, with which will be combined the duties of Head Master of Junior Technical School, which latter is proposed to be opened in September next.
Applicants should possess a University Degree, or its equivalent. Preference will be given to those having practical experience in Engineering.
Further particulars can be obtained on application.
Commencing salary £300 per annum.
Applications, endorsed "Principal," should be in the hands of the undersigned not later than Noon on Monday, June 3rd next.
S. MILLS, Secretary.
Council Offices, Radcliffe, near Manchester.
May 16th, 1918. L 441

COUNTY BOROUGH OF MIDDLESBROUGH EDUCATION COMMITTEE.

The Middlesbrough Education Committee invite

Applications for the following POSTS for TEACHERS in a Junior Technical School to be opened in August next.
Head Master with B.Sc. in Engineering. Salary, £375 (with £16 War Increment).
Assistant Master (Physics and Chemistry). Salary, £180 (with £16 War Increment).
Assistant Master (English and Mathematics). Salary, £180 (with £16 War Increment).
Assistant Master (Woodwork). Salary, £180 (with £16 War Increment).
Applicants should state in detail their educational qualifications and their educational experience in Technical School work, and before making an application should write for a "Report" dealing with the new School. Last day for receiving applications, 5th June, 1918.
EMMERSON BECKWITH, Director and Secretary.
Education Offices, Middlesbrough.
13th May, 1918. L 455

COUNTY BOROUGH OF BARROW-IN-FURNESS TECHNICAL SCHOOL.

Applications are Invited for the Two vacant posts of ASSISTANT LECTURERS in ENGINEERING at the above School. The successful candidates will be required to commence duties in September. Salary £150, rising to £250 per annum, according to scale. In fixing the commencing salary, allowance will be made for previous experience. Full particulars as to duties, &c., and copy of Scale of Salaries may be obtained from the DIRECTOR OF EDUCATION, Town Hall, Barrow-in-Furness, to whom applications must be sent not later than noon on Saturday, 8th June, 1918.
By Order, L. HEWLETT, Town Clerk and Clerk to the Local Education Authority.
Town Hall, 15th May, 1918. L 478

MUNICIPAL TECHNICAL SCHOOL, LONDONDERRY.

The Technical Instruction Committee require the

Services of a Lecturer in Mechanical Engineering, to commence duties in September next. Salary £160 per annum. Forms of Application and further information may be obtained from the PRINCIPAL at the School. Forms of Application must be returned on or before Thursday, 6th June, 1918. L 481
J. A. WILLIAMS, Secretary.

Technical Expert Required for new aeroplane factory, capable of handling inspection department, drawing office, and quality and detail of output. Good salary will be paid to the right man. No one at present employed on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 365.

Chemist Required, for Large Motor and Aeroplane manufacturing concern, must be used to the analysis of both plain and alloy steels. One with experience in other engineering materials preferred. No one on Government work considered.—Apply, stating age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, quoting reference No. A 5124. L 349

Lady Assistant Chemist (WANTED in Rugby district) who has passed either Inter.B.Sc., full B.Sc., or Inter.A.I.C. examination; Organic and Inorganic Analytical work. Organic includes large variety of Insulating and Electrical Engineering materials. Opportunity for progressive experience. Several lady chemists employed. No person already on Government work will be engaged.—Apply, giving training, copies of testimonials, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5241. L 321

Shop Superintendent Wanted, for a large Aircraft Factory in Yorkshire. While some knowledge of aircraft construction is essential, discipline and organizing power are even more important. No person already engaged on Government work will be appointed.—Reply, giving age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 291.

Clerks Required for Purchasing Department, with experience of commercial side of aeroplane manufacture, supplies, &c. No one at present employed on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 263.

Clerk, Chief and Assistants, REQUIRED for Progress and Planning Department of new aeroplane factory, with experience of graphics, tabulation, capacity-schedules, &c. No one at present employed on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 264.

Chief Assistant Required for Electrical Machine Testing for large works in the Midlands. Technical and practical experience essential. No person already engaged on Government work will be engaged.—Apply, giving details of past work, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5156. L 245

A Well-known Engineering Firm in the south of England REQUIRE the SERVICES of an ASSISTANT WORKS SUPERINTENDENT to take charge of night shifts. Must have a knowledge of works routine and have had experience in the handling of labour (male and female). If applicant called upon to do any day-work he will have to supervise all outside work in connection with the Works Department. Applications from discharged officers will be considered. No one already engaged on Government work need apply.—Write, stating salary required and giving full details of experience to, your nearest EMPLOYMENT EXCHANGE, mentioning No. A. 5284. L 400

Foundry Manager.—Wanted immediately, FIRST-CLASS MAN used to light and heavy high-class Engine work in loam, dry and green sand; modern up-to-date methods essential. No one on Government work considered. —Apply through your EMPLOYMENT EXCHANGE, giving age and experience, quoting No. A 5131. L 341

Under Managers and Foremen REQUIRED at an aeroplane assembling works now in construction. Previous experience desirable though not essential. No one at present employed on Government work will be engaged. —Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 266.

Organiser Required to Prepare and carry through a scheme of training workers for assembling of aeroplanes. Live man with good organisation record, and used to Labour Exchange methods and handling of men and women. No one at present employed on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 267.

Engineer Wanted, for Large Modern Cement Works.—Address, stating age, experience and salary required, L 313, Offices of ENGINEERING.

Mechanical Engineer or Capable DRAUGHTSMAN, with practical experience of electrically-driven rolling mills, three-phase supply, for controlled Iron and Steel Rolling Mills in Yorkshire. Must have technical training and experience in Works Costing Methods. No person on Government work will be engaged.—Apply, stating salary, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5266. L 317

Engrenages.—Usine Automo- BILE DÉSIRE s'adjoindre INGENIEUR SPÉCIALISTE ayant une grande pratique et de sérieuses références pour tracé et fabrication d'engrenages silencieux droits hélicoïdaux et coniques pouvant se charger de l'étude et de la direction de la fabrication à l'atelier. Toute rémunération peut être envisagée pourvu qu'elle corresponde à des capacités réelles et à une expérience sérieuse du sujet. Références de premier ordre sont exigées.—Prière écrire à: MAYS SMITH, Bank Buildings, 16, St. James' Street, London, S.W. 1. L 330

Wanted, for Automobile Works, ENGINEER SPECIALIST, with great experience and high references for Laying-out and Cutting of Silent Gears—spur, helical and bevel; able to take care of design and manage manufacture. Any salary will be considered for the right man, provided applicant is really qualified and has a thorough knowledge of the work. First-class references required.—Please write to MAYS SMITH, Bank Buildings, 16, St. James' Street, London, S.W. 1. L 331

Wanted Immediately, Engi- NEER to Re-arrange the Lay-out of Plant in large shop devoted to High-class Steam Engine work. No one on Government work will be considered.—Apply, giving age and particulars of previous experience, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5238. L 343

Three Thoroughly Competent and energetic Assistant SUPERINTENDENTS required for production department of a large firm engaged on aeroplanes, aeroplane engines and similar work. No one already on Govts. work will be considered.—Applications invited from persons having had a thorough training in progress and stores organisation of an intensified character, giving full particulars of experience, names of firms, complete addresses for references, age and salary required, to THE AUSTIN MOTOR CO., LTD., Northfield, Birmingham. L 482

Wanted, Two Good Capable ELECTRICIANS, must have had experience of bells, telephones, and lighting. Plant supervision essential.—Apply, stating age, references, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 5309. No person already employed on Government work will be engaged. L 464

Steelworks Manager Wanted, good man with engineering experience, to take full charge.—Apply, stating experience, salary expected, and when free, "ALPHA," WM. PORTEOUS & Co., Advertising Agents, Glasgow. L 476

Machine Tool Draughtsman REQUIRED for special tools. Good opportunity for a really smart man. Controlled factory. Reply, stating qualifications and salary. No one already on Government work need apply.—Apply your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5327. L 475

Draughtsmen (Electrical) WANTED for the Midlands; preference given to men with experience in the design of D.C. and A.C. Machines or Transformers.—Apply, stating age, experience and salary required to your nearest EMPLOYMENT EXCHANGE, mentioning this paper and No. A. 4895. Nobody engaged on Government work will be engaged. L 474

Tool and Plant Draughtsmen REQUIRED for urgent aero and motor work in progressive Midland works. Permanencies for live interested quick men with initiative and ability. No person already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE mentioning No. A 5316. L 477

Draughtsman Required for Elevator and Conveyor Firm; the post is not a war-time position but permanent to the right man. No person resident more than ten miles away or already on Government work need apply.—Reply, stating age, experience and salary required to BOX 501, T. B. BROWN'S Advertising Offices, 163, Queen Victoria Street, E.C. 4. L 485

Draughtsman Wanted with sound mechanical Engineering knowledge and training. North London District. No one at present on Government work or residing more than ten miles away need apply.—Address L 480, Offices of ENGINEERING.

Civil Engineering Draughts- MEN REQUIRED, for Government work in Fifeshire; one with good experience in designing structural steelwork and ferro-concrete; the others to have a good general experience of general Civil Engineering work and to be quick and accurate Surveyors.
Must be Ineligible for Military Service.
Applications, stating age, experience and qualifications, salary required, with copies of recent testimonials, to be addressed to BOX No. 1449, WILLINGS, 125, Strand, London, W.C. 2. L 414

Draughtsmen.—Several Men REQUIRED for Mechanical Engineering work for Controlled Factory in Midlands. Must have had some practical experience. Knowledge of Textile or Printing machinery desirable, but not essential. Good opportunities for suitable men. Also several good JUNIORS, with Drawing Office experience. No one already on Government work will be engaged.—Apply, stating full particulars of salary required, age, experience, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5061. L 416

Capable and Experienced DRAUGHTSMAN WANTED for Jig and Tool design on high-class repetition work, near London. No person already on Government work will be engaged.—Apply, stating age, experience and salary, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5160. L 248

Wanted, Experienced and Capable Jig and Tool DRAUGHTSMAN, preferably with experience of motor vehicle manufacture. London District. No person already on Government work will be engaged.—Apply, stating age, salary and full particulars of experience to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 5079. L 256

Draughtsman Required to TAKE CHARGE of Coal Washery Department. Experienced man only need apply.—Full particulars in the first place to K 624, Offices of ENGINEERING.

Draughtsmen.—A Controlled Establishment in the West Riding of Yorkshire, engaged on important high priority work, REQUIRE the SERVICES of a competent MAN, with first-class experience in General Engineering work; also experienced MAN for medium size machine tool work. No person already on Government work will be engaged.—Apply, stating full particulars, to your nearest EMPLOYMENT EXCHANGE, mentioning A 4965. K 869

A Lady Tracer is also REQUIRED. The above positions are permanent to reliable individuals. No person already on Government work will be engaged.—Apply, stating full particulars, to your nearest EMPLOYMENT EXCHANGE, mentioning A 4964. K 869

Draughtsmen Wanted, for Aeroplane work in Government factory. Previous experience in aeroplane design not absolutely necessary, but sound knowledge of mechanical principles essential. Good prospects for right men. No person already on Government work will be engaged.—Apply, stating experience, age and salary required, to your nearest EMPLOYMENT EXCHANGE, quoting reference No. 4126. L 171

Draughtsman Required, with good experience in design of Steelworks Machinery preferred, although applications from high-class men with other experience would be considered. No one already on Government work will be engaged.—State age, experience and salary required and when at liberty, to your nearest EMPLOYMENT EXCHANGE, quoting No. A 4694. K 398

Draughtsman (Jig and Tool) WANTED for large Aeroplane works in Lancashire district, knowledge of press work, tools for automatics (Cleveland and Acmes, Capstans) and all woodworking machines. No person already on Government work will be engaged. Only experienced men need apply, stating age, full experience and salary required, at your nearest EMPLOYMENT EXCHANGE, quoting No. A 5013. L 9.

Draughtsmen Required with experience of aeroplane work and jig designing, &c. No one at present employed on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 268.

Two or Three Good Draughts- MEN WANTED by Yorkshire firm, engaged on important Government Contract. Must be experienced in high-class instrument work or light engineering. Good wages offered to men of ability. No person on Government work need apply.—Apply, stating age and giving full particulars, to your nearest EMPLOYMENT EXCHANGE, quoting L 385 and this Journal.

Steelworks Draughtsmen (three) REQUIRED for large Steelworks, Sheffield district. No one already employed on Government work will be engaged. Good general mechanical experience essential.—State full particulars, including age and salary expected, to your nearest EMPLOYMENT EXCHANGE, mentioning ENGINEERING and L 339.

Wanted, Draughtsman, Ex- perienced in the design of all classes of Hydraulic Machinery. No one already employed on Government work or residing more than 10 miles away will be engaged.—Apply, stating age, experience, &c., to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 411.

Draughtsman, Mechanical Engineering. WANTED for Controlled Works in the Midlands. Experience in small, high speed engines preferable. No one employed on Government work will be engaged.
Apply, stating age, experience, salary required and when at liberty, to your nearest EMPLOYMENT EXCHANGE, quoting ENGINEERING and A 5291. L 361

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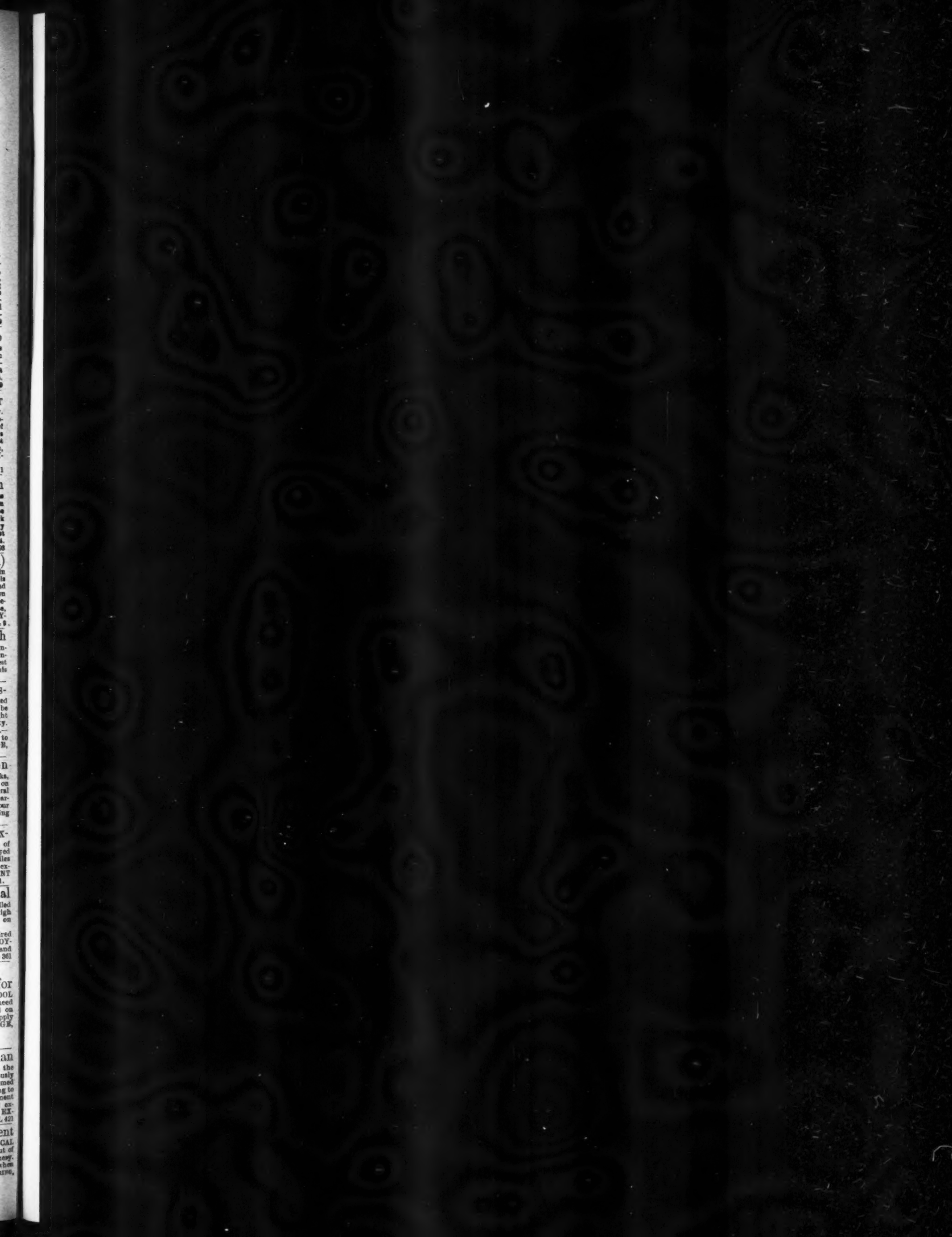


THE DEFINITION OF HARDNESS.

By W. CAWTHORNE UNWIN, LL.D., F.R.S.

BEYOND doubt the various methods of determining hardness have been most useful in the workshop. But there is a general impression that hardness numbers give arbitrary and relative values only. Certainly that is so in the case of the mineralogist's scratch test, which shows that one material is harder than another without any indication of the quantitative difference. So much is this the case that physicists throw doubt on there being any quality of hardness capable of definition. The commonsense engineer's view is that one material is harder than another if it indents it when pressure is applied. Osmond defines hardness as resistance to permanent deformation and it must have some relation to the yield-point of a material. For sixty years some form of indentation test has been used in discriminating hardness. In France a monkey or hammer, faced with a hard steel pyramidal or conical point, was dropped from a known height on the specimen. The reciprocal of the width of the impression was taken to measure the hardness.

In 1895 and 1900 Lieutenant-Colonel Martel communicated two very interesting and valuable papers to the Paris Congress on testing materials. He used the falling monkey method, with various forms of indenting points, and various heights of fall. He established conclusively that the work expended in indentation, notwithstanding these variations of the conditions, is proportional to the volume of the indentation.

If V is the volume of the indentation, P the weight of the monkey and F the height of fall:

$$D = \frac{P F}{V}$$

is constant for any given ductile material. Then D in kilogramme-millimetre units is Martel's hardness number.

It is easy to see that D is the amount of work necessary to cause a cubic unit of indentation and is independent so far as the tests go of the form of the indenting body.

Further, a few tests were made with a gradually-applied load and the same law was satisfied, except that D was about 20 per cent. less in the case of a gradually applied load. Probably this was due either to there being some loss of work in vibrations, &c., in the impact tests; or to inexactness in determining the work expended in tests by a gradually-applied load.

About 1900, Brinell introduced the ball indentation test now so extensively used. The standard ball is 10 mm. diameter and the load 3,000 kg. The load must rest on the ball for some seconds till the indentation is complete. If P is the load and A the area of the spherical surface of the indentation, then Brinell's hardness number is:

$$H = \frac{P}{A}$$

kilogramme-millimetre units. The reason for dividing P by the spherical surface of the calotte is not obvious and it is not known that Brinell has given an explanation.

Let the annexed figure represent the Brinell ball of radius r, C E D the indentation of depth h at any instant, A E B the indentation of depth h_1, when the indentation is complete under the load P. Let a be the radius of the circle C D, and a_1, that of the circle A B.

When the indentation has reached a depth h, the pressure on the area C D will be:

$$k \pi a^2 = \pi k (2 r h - h^2)$$

where k is the intensity of pressure under which the material yields or flows in the conditions of the test. Let the indentation increase to $h + dh$. The work expended will be

$$\pi k (2 r h - h^2) dh$$

or as h is small compared with $2r$, the work is:

$$2 \pi k r h \, dh$$

and the total work expended in indenting to a depth h_1, is:

$$2 k \pi r \int_0^{h_1} h \, dh = \pi k r h_1^2$$

The case of a deep indentation need not be considered.

The volume of the spherical calotte A E B is $\pi r h_1^2$. Hence Martel's hardness number is:

$$D = \frac{\pi k r h_1^2}{\pi r h_1^2} = k$$

When the indentation is of depth h_1, the pressure on the area A B is:

$$P = k \pi a_1^2 = \pi k (2 r h_1 - h_1^2)$$

or, neglecting h_1^2, as before:

$$P = 2 \pi k r h_1$$

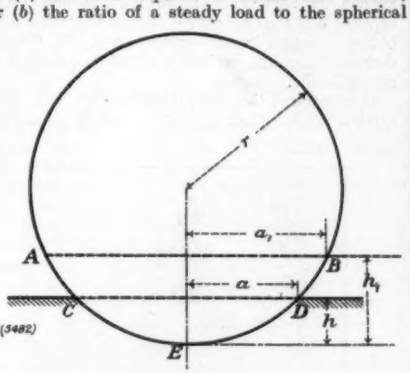
The spherical surface A E B is $2 \pi r h_1$. Hence Brinell's hardness number is:

$$H = \frac{\pi k r h_1}{\pi r h_1} = k$$

Consequently:

$$D = H = k$$

and hardness of a ductile material may be defined as (*a*) the work required to indent unit volume, or (*b*) the ratio of a steady load to the spherical



surface of a ball indentation, or more generally and simply the intensity of pressure on the area A B of the surface indented at which the material yields or flows in the conditions of an indentation test. That is when the flowing molecules are surrounded by less strained material.

As far as the author knows the identity of Martel's and Brinell's hardness numbers has not been pointed out before. Martel's papers seem to have been neglected. Here are some of Martel's figures obtained by the falling monkey test:—

	D =
Firth diamond steel	
Tempered in oil	613
Untempered	460
Martin steel, tempered in water ...	416
Gun steel	300 to 455
Wrought iron	226

So far as the quality of the material can be guessed, these numbers are such as would be given in a Brinell test.

SCIENTIFIC SIGNALLING AND SAFETY AT SEA.

IN the British Admiralty pilot and sailing directions still extant the sailor is informed that there is no help in a fog, save unreliable fog signals and the use of the lead. "Sound is conveyed in a very capricious way through the atmosphere. Apart from wind, large areas of silence have been found in different directions and at different distances from the signal station, in some instances even in close proximity to it. The mariner should not assume that, because he fails to hear the sound, he is out of hearing distance; that he is at great distance, because he hears the signal faintly; that he is near it, because he hears it plainly; that the signal has ceased sounding, because he does not hear it; and that the distance and the intensity of the sound on any occasion are a guide to him for any future occasion. The lead is generally the only safe guide in fogs." These words were quoted by Professor John Joly, F.R.S., of Trinity College, Dublin, in introducing his two Tyndall lectures on "Scientific Signalling and Safety at Sea," delivered at the Royal Institution on April 9 and 10. Much that Professor Joly advocated in these lectures, which we abstract, is still in the experimental stage. That it remains in that stage, in spite of scientific progress, is largely due to the war, and in general due to a justified conservatism of the sailor. When normal conditions have been restored, however, many promising suggestions will have to be thoroughly tested, and the antiquated navigation rules consequently revised. More is at present done for the comfort, than for the safety, of passengers at sea, and some of the means suggested for increasing safety depend upon devices already in use for the transmission of news.

Dealing first with recently introduced coastal signals, Professor Joly remarked that the Admiralty directions he had quoted were not intended, of course, to imply the worthlessness of aerial sound signals. But recent advance in science had supplied additional safeguards, in the first instance "synchronous signals." When we saw the flash of lightning, and heard the thunder two seconds later, we concluded that the storm was $2 \times 1{,}100$ ft. away, since sound was propagated at 1,100 ft. per second. If the Dover express travelled at 40 miles per hour, it would reach London, 80 miles distant, in 2 hours. To a certain extent a man in London could follow the progress of the train, if a friend in Dover sent him a signal when the train left, and again at intervals of 15 minutes; whenever he heard the signal, he would know that the train was 10 miles nearer London. In this way the sailor could benefit from synchronous signals without the aid of a stop watch. If a lightship near shore discharged a gun and at the same moment gave a light flash; hearing the report $3\frac{1}{2}$ seconds after seeing the flash, the sailor would know that he was somewhere on a circle of radius $3\frac{1}{2} \times 1{,}100$ ft., and the flash would give him the bearing of the station. But the flash might be obscured by fog and rain, and the sound was difficult to pick up in stormy weather, while there were the "zones of silence" already mentioned. The sound waves seemed to arch over certain areas, and would thus travel on indirect, longer paths, conveying a wrong idea as to distance. Yet the simple aerial signal should not be condemned any more than lighthouses were. Automatic bell buoys, common on our coasts, were often combined with occulting lights. The bell rocked up and down with the motion of the water, and a horizontal vane beneath the bell oscillated and compressed, through a ratchet, a spring which was finally released and actuated the hammer. Even in the calmest weather three or more strokes might be given per minute, not at regular intervals, but fairly of the same intensity, and the number of strokes could be limited to, say, three per minute. When a light flashed up simultaneously with the stroke, and the flashes were spaced to follow one another at intervals corresponding to a sound-propagation of one cable (0·1 nautical mile) *i.e.*, at a little more than half second, then the sailor, counting the flashes between consecutive bell sounds, would see a second flash after the sound had travelled one cable, and a tenth flash, after the sound had travelled 9 cables and so on, and he could thus ascertain his distance from the buoy without the use of a stop watch. This was valuable for small craft not equipped with signalling appliances.

With the aid of radiotelegraphy and submarine signalling, these devices could be much perfected. As sound travelled in water at the rate of 4,800 ft. per second, the submarine bell-stroke would lag behind the radio dot by 1·2 seconds for each nautical mile traversed, if the signals were simultaneous; and simultaneous air and water sounds would differ by 4·3 seconds per nautical mile traversed. The rate of propagation of sound through water had really been determined on these lines by Collodon and Sturm in 1826, in the Lake of Geneva—the bell stroke ignited some powder, and the sound was listened to in a trumpet immersed in the water. Divers were well aware of the startling audibility of sound under water. Experimenting years ago off the Dublin coast, on means of ascertaining the depth of the water under a moving vessel, Professor Joly had observed that the explosion of a small cartridge containing $\frac{1}{2}$ oz. of gunpowder, fired at the bottom of the sea, was easily perceived a mile away in open boats (unprovided with any form of sound-receiver) as a blow striking the bottom of the boat.

The modern submarine bell (Fig. 1),* now largely used, is made of bronze; it weighs 220 lb., and

* We are indebted to the Submarine Signalling Company for two of our illustrations.

has a period of 1,215 vibrations in water. The striking mechanism is contained in the cylindrical casing above the bell. The bell is suspended by a chain at a depth of about 18 ft., and the cylinder is fed with compressed air from a reservoir on shore or on the lightship, which is kept charged by an engine. The United States tested five of these bells for 51 days of continuous ringing (at intervals of 6 seconds) in 1906; their introduction into England had been slow, although the Admiralty had reported favourably on them in 1906. For use on the sea floor the bell is generally provided with electric power, and suspended from the apex of a steel tripod, 25 ft. high and weighing 3 tons, down to depths of 25 fathoms (at the Stack Lighthouse, Holyhead, *e.g.*). The ordinary submarine bell-buoy is operated by the waves in the way above indicated; the whole mechanism is housed in a boiler plate receptacle beneath the buoy, which is open below, only the bell itself protruding; thus the mooring chain cannot foul the bell or its mechanism.

Passing to sound-receiving devices on board, Professor Joly said that at first these devices had been towed astern or been attached to the outside of the ship; but it had been found that listening to the acoustic vibrations which the ships' walls picked up from the sea was most effective. A small cast-iron tank was screwed to the inner wall which formed one of the sides of the tank; this tank should be low down in the water. The tank was filled with water, and two microphones were immersed in it, one more forward than the other; there was one tank on each side. Wires from the microphones passed up to the bridge, and the two receivers, one on each ear, were connected with the fore and the aft microphone of the same tank; by means of a switch the observer listened alternately to the microphones on the port and on the starboard. When the source of sound was right ahead, both telephones would speak equally loud; when the sound came from the port side, that sound would predominate; when the sound came from aft, the telephones would not respond except at close distance; that was partly due to the disturbance of the water by the propellers. To ascertain the bearing of the bell more clearly the ship was swung. The best position for the tanks was forward in the bows; but it depended upon the ship lines, and the most suitable position was determined by experiment.

Though the combination of submarine signals and radiodots was the least liable to failure, it was not the most sensitive method, and its use was practically restricted to large high-speed vessels which required to determine their position within half a mile or less. If the dots were sent at intervals of 0·6 second, the bell stroke would lag by the interval between two dots for each half mile traversed. Five miles off the coast, the lag would amount to 10 intervals, the bell coming in with the eleventh dot; estimates within a quarter mile would be possible. In these cases the observer listened with one ear and one telephone to the bell, and with the other to the dots.

Professor Joly then referred to the interesting experiments on synchronised signals—hardly known in this country, he remarked—which the United States Hydrographic Department had conducted in September, 1911. From the Nantucket Shoal Lightship (east of New York) three signals were given simultaneously once every minute: a steam whistle W, a submarine bell-stroke B, and radiodots, or ticks (lasting 2 seconds or 3 seconds) R. The signals were received on the cruising steamer Washington, the interval between B and R being determined within a few tenths of a second by a Hack chronometer, and the W–R interval within half a second by a stop watch; from these observations the position of the Washington was deduced assuming the velocity of sound in air to be 1,132 ft. (at the air temperature 68·5 deg. F.) and in water (at 66 deg. F.) to be 4,794 ft. per second; the weather was calm and hazy with light airs from west-north-west. The true course of the ship was further determined by rangefinder, compass, and log; a tidal current northward was allowed for. The Washington first steamed due west for 8 miles, turned and headed east-south-east, passing the lightship on the port beam at a distance of 3,450 yards, went on in the same direction for 8 miles further, then turned north-west, passing the lightship again on the port beam at 4,600 yards, and then turned finally south-east back to the station. On this course, with the station at first right astern, the whistle was lost at ½ mile (zone of silence ?), the bell at 2 miles from the station; the bell was picked up again as soon as the ship had turned east-south-east, at 7·6 miles, the whistle only when the ship was once more within 4 miles of the station; 5½ miles from the station the bell was lost again, the station being then astern, 19 deg. off the course, whilst the whistle remained longer audible this time, within 7½ miles from the station. On turning north-west the bell was at once picked up again, at 8·6 miles from the station, the whistle only at 6 miles; afterwards both the acoustical signals remained audible throughout. The track of the Washington as deduced from these observations, forms a curious zig-zag line, sometimes on the one, sometimes on the other side of the true course, but on the whole fairly correct, though in one extreme case the distance deduced from the whistle and the bell differed by nearly 1 mile.

It was found thus that the submarine bell sound carried further than the aerial whistle sound and

FIG. 1.

was not subject to capricious irregularities, but that the submarine signal was badly received from astern with the microphone tanks forward in the bows. The Hydrographic Department was satisfied with the experiments, and the Fire Island Lightship, off New York, was fitted up for the three synchronous signals as indicated. There was one modification, however; the bell-stroke preceded the first radiodot by 0·6 second. Thus a listener at half a mile distance heard both the signals together, and if he counted 10 radiodots before hearing the bell, he was 10 half miles off; that was a simplification, Professor Joly pointed out, but if the sailor were within half a mile, he would hear the bell before the dot, which was confusing. In a recent report issued by the British Board of Trade it was mentioned that the apparatus of this Fire Island Lightship was operated during fog, mist, rain or snow; that the range was limited to the bell-receiving equipment on board ship, which was practically within 6 miles or 7 miles; that the bell gave 6 strokes, paused, and then 8 strokes, once every 38 seconds. Hence, the lecturer remarked, two unsymmetrical groups of bell-strokes were emitted, probably to facilitate the identification of the station, the lightship spelling out its name by the signals. The size of the antenna was such that the radio-signal range was not much greater than the bell range, to avoid interference with other radio signals.

The oscillator of R. A. Fessenden, the lecturer proceeded, was a rival of the submarine bell of astounding promise. It acted both as transmitter and receiver, it had a range of 30 miles and more, could convey Morse signals to these distances, allowed of determining the depth of the water beneath the moving ship and the location of icebergs by reflected sounds, and seemed even to be utilisable as a telephone over short, but useful distances. The Fessenden oscillator, as well as the H. C. Berger apparatus (in which longitudinal vibrations are emitted by a wire), were noticed in our issue of April 16, 1915 (page 438) in connection with a paper read by J. B. Millet and F. L. Sawyer before the Society of Naval Architects and Marine Engineers at New York. The Fessenden oscillator may briefly be described as a powerful electromagnet on an alternating circuit (500 periods per second), in the cylindrical pole gap of which a copper cylinder, 9 in. in diameter, moves endwise to and fro; the cylinder is connected with the oscillating diaphragm, which may be part of the ship's side, the moving parts weighing more than 100 lb. The practical audibility ranges stated at the New York meeting to have been attained in the first experiments were smaller than the 30 miles claimed by the Submarine Signal Company, as Professor Joly mentioned. But improvements had been effected, and there were certainly new possibilities as regard synchronous signalling.

With the aid of this oscillator a ship steaming at

Fig. 2.

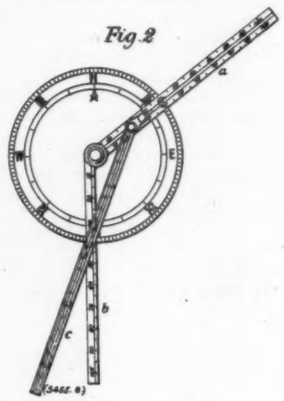
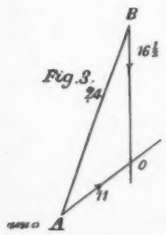


Fig. 3.



25 knots might ascertain her distance from the land and the bearing of the signal station, and thus her right course, more than an hour before making port, in any state of the atmosphere, and it could further find out in what depth of water she was moving, and whether there were any icebergs near. For this purpose a commutator with one conducting segment was combined with the oscillator; two brushes bore against the commutator, the one being joined to the alternating generator, the other to the telephone receiver. As the commutator revolved, the oscillator was momentarily excited; the sound travelled to the bottom of the sea, was reflected back and, acting on the oscillator, generated current in it; this current was heard in the telephone when it happened to be in circuit at the instant the reflected sound came up; the setting of the telephone brush would thus determine the depth of the water. In 8 fathoms the echo would take $\frac{1}{40}$ second to come up, and this echo was, in the experiments, heard without the use of the receiver. In other experiments the distance of an iceberg 450 ft. long, 150 ft. high, was determined by echo while the United States revenue cutter used in the trials kept within distances ranging from 0·5 mile to 2·5 miles of the berg. The echoes were sufficiently loud at 2½ miles to be heard all over the ship, although the oscillator was not properly installed, but only lowered overboard.

These wonderful achievements, Professor Joly

continued, seemed even to be surpassed by those secured with the aid of the radiophone at Point Judith, at the western approach to Narragansett Bay, Rhode Island. A phonograph, started by a switch, called out the name of the station every 5 seconds; after three repetitions a much feebler voice uttered the warning: "You are getting closer, keep off." The receiving apparatus, the Submarine Signal Company had informed the lecturer, was very small and required so little tuning, that a few minutes' instruction sufficed for its use by inexperienced men; the sailor would first hear the "Point Judith," and then the warning. With the aid of radiophone stations and, further, of radiogoniometers (wireless compasses) for the determination of the direction in which the sound arrived and thus the bearing of the station, a ship would be able to proceed from headland to headland without seeing any lights. These radiosignals, which were only meant for a limited range, and especially the radiogoniometer, were, however, affected by atmospheric conditions.

Dealing in his second lecture with the prevention of collisions at sea, Professor Joly remarked that he did not wish to abrogate the old-established methods of whistling and listening, nor the old rules as to the right of way and slowing down in thick weather. But submarine signalling, the radiogoniometer (*e.g.*, the Bellini-Tosi directive transmitter) and radiotelephony had placed means at our disposal, by the aid of which good speeds might be maintained at sea, and the time had come for a complete reconsideration of the problems. As a first essential condition the future Board of Trade would have to require that a continuous watch be kept in the wireless room during thick weather on all ships. The operator should send and receive signals, the officer of the watch interpret and direct them; that division of duty would contribute to safety. The submarine signals could be given by bell (to be placed in a recess in the ship's bottom) or by oscillator; low power radiosignals he would, suggest, should be emitted at intervals of 5 minutes. Two ships, A and B, approaching one another, would exchange code signals giving course (in degrees, counted clockwise) and speed; thus A, steaming 53 deg. (about east-north-east) at 11 knots, would learn that B was going 180 deg. (south) at 16½ knots. A and B could only collide if simultaneously reaching point 0 (Fig. 3), and the conditions of a possible collision might be characterised by (1) the danger bearing, (2) the danger rate of approach, (3) constant bearing, (4) constant rate of approach. In the case mentioned a collision could only occur when B was bearing about north-north-east from A, and A south-south-west from B, and if they approached one another at the rate of 24 knots. Hence by observing the actual bearing and actual approach, A could tell whether a collision was likely, and in most cases A would at once know that no collision was to be feared. The three factors involved were position, speed, course, and the distance between the ships would decrease at the maximum rate possible if a collision were to occur. The rate of approach was the third side of the triangle A B 0, which the sailor could determine, without geometrical construction, by the aid of Professor Joly's "collision predictor."

This predictor (Fig. 2) consisted of a circle upon which compass bearings were marked and which carried two limbs, *a* und *b*, pivoted at the centre and divided in knots; on a cursor slipping along *a* was further pivoted the arm *c*, which was provided with a transparent scale. The sailor set *a* to the course of his ship A, *b* to the course of B, then moved the cursor along *a* up to the division marking his speed, and inflected *c* until it intersected *b* at a distance (on *b*) proportional to B's speed; he had then constructed his triangle, and could read off the maximum velocity (danger rate of approach) of 24 knots on *c*. In order to facilitate the estimates, *c* was graduated to mark the amount by which A and B approached within 2 minutes, that being the interval separating the distance observations by synchronous signalling; in the case considered that rate of approach would be $24 \times 2/60 = 0{\cdot}8$ sea mile in 2 minutes. The direction of *c* at the same time gave the danger bearing, better to estimate which a parallel motion up to the centre could be imparted to *c*. Held in the true compass position, the direction in which *c* was pointing told A in what direction B was approaching and also the distance separating the ships and the time taken to cover that distance—as if A were watching the approach of B on a chart.

When A felt uncertain about his determinations, he signalled to B that he was going to determine the distance; B then prepared to listen, picked up A's bell, and told A his distance; if that distance were 5 miles, they would both know that they could only collide after 12 minutes (the approach being 0·8 miles in 2 minutes). If repeated signalling after 2 minutes indicated 4 miles, there was danger. These observations, and the times still to go were entered on a sheet and compared with the danger distances (from the predictor); if they agreed, there was danger. Collision could only occur with conditions maintained when the rate of approach was constant; that constant rate could also be made a criterion of danger (4), as could likewise be the fact that the bearings remained constant (3).

But there were serious objections to the constant bearing method, whether relying on the radiogoniometer or on submarine signals. The ship's course had to be altered during these hurried observations; the ear estimate of the intensity of sound was always deceptive, and though the Bellini-Tosi directive transmitters had much been improved and readings within 1 deg. were claimed, there seemed to be little variation in the maximum intensity of current over a range of 10 deg. from the direction of the signal. The fourth criterion, the constancy of the rate of the approach, did not involve knowledge of course and of speed; it required periodic emission of synchronous signals by A which B received, reporting the distance deduced; if the rate of approach diminished, the danger was past. If a third vessel C came within the range of audition while A and B were exchanging signals, *C* should keep out until A and B were clear, not to confuse their signals by her own; *C* might be restricted to acoustic signals, Professor Joly suggested.

All these methods would, of course, have to be thoroughly tested before adoption. Other improvements in radiotelephony might further reduce the risk of collisions. By phonograph a vessel might call out her name as a distinguishing signal, and also her course and speed, when occasion arose. Professor Joly did not disguise the eccentricities of radio signals, which may be heard at astounding "freak" distances or may become almost indistinguishable at small range. He ignored one difficulty, however, that of language. Phonographs generally speak with a peculiar accent; we do not pretend to know what a Spaniard, *e.g.*, might understand, when "Point Judith" was shouted at him in American. But sailors somehow manage to understand one another, and the manysided difficulties will be met as they have been under other conditions.

THE IRON AND STEEL INSTITUTE.

(*Concluded from page* 511.)

THE first paper taken at the meeting on Friday morning, the 3rd inst., was the one by Mr. B. Talbot, on the

PRODUCTION OF SOUND STEEL BY LATERAL COMPRESSION OF THE TOP PORTION OF THE INGOT.

It was read in abstract by the author, who exhibited a number of photographs of transversal sections at different parts over the height of several ingots made by his process, and of vertical sections through rails obtained from similar ingots. The author stated that he was continuing his work and investigation with a view to obtain a larger percentage of commercially sound steel from the upper portion of the ingot. He referred to his former contributions on the subject and to those of Sir Robert Hadfield and Dr. G. K. Burgess.* Mr. Talbot had now decided to use a refractory-lined top to the moulds to localise the pipe in the ingot and confine the segregation to the upper portion more than was the case with iron moulds. The refractory lined top also kept the surface of the top portion of the ingot hotter than the lower portion which was in contact with the iron sides of the mould. The investigation was continued by laterally compressing the top portion only, as it was thought unnecessary to endeavour to improve the lower 80 per cent. of the ingot, this being sufficiently sound and regular in composition for all ordinary purposes when refractory tops were used. The apparatus was a hydraulic press which made a depression upon two or upon all the four sides of the ingot; the depressions were of a larger area than the cavity which would form in the ingot were it allowed to go cold in the ordinary way. The press was a compromise upon the Whitworth and Harmet methods, which latter embrace the compression of the whole ingot in the mould itself. Mr. Talbot removed the ingot from the mould and pressed the upper portion of the ingot at a time when the outer envelope was thick, and strong enough to retain the pressure, but whilst the centre was sufficiently liquid. Hitherto, ingots of 3½ tons to 5 tons had always been used, and they had all been cast in moulds having refractory-lined tops. The average temperature of a number of 3½ ton ingots when stripped between an hour and an hour and a half after casting was found to be 1,140 deg. C. at the top in contact with the refractory-head, and 940 deg. C. at the bottom. No unsound steel was found in any instance below 90 per cent. of the whole ingot; an average of 95 per cent. of sound steel was obtained in the ingots pressed. Although the pressure was applied in the upper 15 per cent. of the ingot only, there was no doubt that its influence was felt somewhat lower, and probably could be traced to a distance of 20 per cent. to 25 per cent. from the top. The carbon percentage became somewhat lower in the centre, after pressing, for about 10 per cent. of the area of the whole tranversal face than the average of the ingot; but for rails, a somewhat softer centre could hardly be considered objectionable, since a hard outside wearing surface was desired. The prints exhibited showed that sound commercial steel could be obtained from the compressed ingot to within 3 per cent. or 4 per cent. of the top; the whole ingot, therefore, minus the necessary cropping of the rolled product, could be satisfactorily made use of. A print was exhibited showing a Sandberg high silicon rail, 95 lb. per yard, rolled out of a discard of 20 per cent. from the top of a pressed ingot, without any cropping whatever. Mr. Talbot's method, a short description of which concluded his paper, consists in providing the ingot mould with a suspended central core, and in pouring liquid slag into the space formed between the core and the recessed side of the mould. As soon as the slag has become solid, the core is removed, when the mould can be brought into use and the steel cast against the slag lined part. With a suitable blast furnace slag, from 15 casts to 20 casts can be obtained before renewal is necessary. With a more refractory slag, such as that from an acid open-hearth steel furnace, a longer life may be expected for the top.

The discussion was opened by Mr. E. H. Saniter, who congratulated the author on the great perseverance he had shown in carrying out his investigations and felt sure that all the members hoped he would meet with continued success. The author had stated that in some cases he had obtained 100 per cent. of sound steel, adding that it was to be understood that no internal defects were met with; Mr. Saniter asked whether there were really no defects, and also whether there did not occur cracks on the skin of the upper portion. This latter possible occurrence might be a source of trouble. The author, he thought, had devised a very ingenious method for making the refractory top of the ingot, it was a great advance upon the refractory heads hitherto made.

Dr. Stead, who followed, said he had seen the plant in operation and had found that it worked satisfactorily; all the claims made by the author had come true, so far as he (the speaker) had been able to ascertain. The sections made of the ingot proved that soundness was arrived at. Dr. Stead had asked the author whether, if he cast at a low temperature, he would have the pipe lower down, and the reply to this was that there was no secondary

* See ENGINEERING, vol. lxxx, pp. 434, 462, and 481, vol. xcv, p. 626, and vol. xcix, pp. 538 and 561.

pipe. It was true that if there occurred a rush of ingots to be submitted to pressure, difficulties might arise, and what was wanted was an equal and regular distribution to the press. The slag refractory top was a very simple one and would lead to a decrease in cost compared with the ordinary types of refractory heads, and he congratulated the author upon the success of his methods.

Mr. Cosmo Johns stated that he would contribute to the written discussion on the subject, but wished to support Dr. Stead's remarks on one point and to express his admiration of the ingenious slag head. The arrangement, however, might perhaps only be applicable to ingots cast with the large end downwards; if the small end of the ingot were downwards the device might perhaps not work quite so well. But this was a feature he had not studied and would look into.

Dr. W. H. Hatfield who followed said he had read Mr. Talbot's paper with great interest; the author's experiments were always keenly watched by all. He asked whether the temperature of 1,140 deg. C. at the top of the ingot in contact with the refractory head of the mould had been taken by an optical pyrometer, and whether there was or not a steep gradient in the temperatures of various parts of the ingot. He (the speaker) understood that from the earlier experiments of the author he depended upon squeezing the ingot and forcing out the segregation. For rails and dealing with large ingots, the process described in the paper might be a success, but the manufacture of alloy steels was a different proposition. He also congratulated the author on his method of making the refractory head.

Mr. E. F. Law found that the author's present process was a distinct advance on his former ones. With reference to Mr. Cosmo Johns's remark, he (the speaker) added that the author's idea was to produce a good ingot, and if he succeeded in that there was no objection to the casting with the large end downwards.

Mr. A. Hutchinson expressed the opinion that the author had shown the members that he obtained sound ingots, and how they could organise their own works; what remained for them to do was to see whether they should apply his methods.

Mr. H. H. Ashdown endorsed the opinions which had been expressed by the former speakers and added that Dr. Hatfield had raised the important point regarding the application of the process to special steels. In this latter connection he would add that a similar compression device was adopted several years ago at Woolwich for obtaining sound ingots, but it had been found that the segregation could not be removed until compression was applied immediately upon the termination of the casting operation. He (the speaker) was also interested to know whether any fractures occurred during the author's process of compression.

Dr. F. Rogers found the author's process an advance upon his former ones. It sufficed to look at the photo-prints exhibited to see that there was not only a gain in quality at top, but there was also more steel available. He asked whether the author's outline of his dies in the press, as printed in the paper, was something like that of the actual dies. If so, did he get any indentations on the ingot? It would be interesting to know, also, how deep the dies were pressed in, or what was the section of the ingot obtained at the top ultimately for rolling down. The form of the dies was an important point, because there might occur a cutting or tearing effect; this might obviously be the case with the form of dies sketched in the author's paper. He would also like to know whether the core used by the author for pouring his slag head on the top of the ingot mould was a casting, and how he removed this core on the slag head being completed. Further, it would be interesting to know whether there occurred any flaking or chipping of the refractory slag head when teeming the steel through it into the ingot mould, and therefore the risk of fragments of slag from the head being carried into the steel.

Mr. Talbot, in the course of a brief reply, stated that with an ordinary brick refractory head the surface of the ingot at the top was not even, steel ran in the joints between the bricks and produced fins; it was important, therefore, to devise a means for giving a satisfactory surface, and this was obtained with his slag moulded head. In regard to the position of the segregation, he could extrude some of the segregation, but he did not desire this so much as to place it in the condition and position he wanted, and he was satisfied that he had met the point. With reference to the casting of the large end upwards, a point mentioned by Mr. Cosmo Johns, Mr. Law had given the reply, and if he (the speaker) could get what he wanted in comparatively cheap steel, especially rail steel, by following his process, he saw no reason why he should change his method of working. He was glad to hear of the research work done in Woolwich, mentioned by one of the members; Woolwich had certainly not made the world aware of what they had done in that respect. He had not sectioned ingots vertically, he had not the men, machinery or the time to do it; for his purpose he needed no vertical section. He had no intention of letting his ingots get cold before submitting the top to pressure; if some of them, however, grew cold he would probably leave them a little longer in the press. In the matter of the shape of the dies, it had been necessary to fit and try. The die shown in outline in the paper was the first one he had used. The dies made a depression; a sufficient margin from the corners of the ingot had to be allowed, and the dies should not go too deep because of the subsequent rolling of the ingot. If the dents were too deep there might be caused an undesirable lap in the mill. No slag from the refractory head dropped into the ingot mould with the steel; there was no trouble from that point of view whatever, and no flaking. Acid open-hearth slag was very dense; the next best was that from Cleveland grey iron. Basic open-hearth slag had not been found satisfactory so far; it did not stand at all like the other two.

On the motion of the chairman, the author was awarded a hearty vote of thanks for his communication.

NON-METALLIC INCLUSIONS: THEIR CONSTITUTION AND OCCURRENCE IN STEEL.

The next paper taken was the one having the above title, by Dr. Andrew McCance; it was read in abstract by the author, who, in his opening statements, said that the important part which non-metallic inclusions played in causing failures and producing defects in all manner of steel products was not yet fully realised. Fully 90 per cent. of the failures due to faulty material which had come under the author's notice had been traceable to the number of non-metallic particles which it contained. The paper dealt with inclusions as a source of weakness in stressed material, with the position of inclusions in relation to the ingot, the effect of manganese, aluminium, &c., on the steel, the influence of temperature on the prevalence of inclusions, and so forth, all points which were considered in great detail by the author. We hope to reproduce his paper in a forthcoming issue.

NOTE ON INCLUSIONS IN STEEL AND FERRITE LINES.

Dr. McCance's paper was taken for discussion together with a "Note on Inclusions in Steel and Ferrite Lines," by Dr. J. E. Stead, who read his contribution in abstract. Dr. Stead stated that his object was to place on record a large number of experiments to determine whether or not non-metallic inclusions in steel induced ferrite to crystallise round them. It was Mr. Ziegler who first suggested, added Dr. Stead, that the cause of segregation was the inclusions; other authorities had accepted that view, but as opinion was divided, it seemed advisable to dismiss preconceived conclusions and to start afresh to settle the question once for all. Dr. Stead's investigations led him to state that evidence appeared to be conclusive that non-metallic inclusions and empty cavities in steel did not lead ferrite to crystallise round them, and that it was the phosphorus—almost always associated with the inclusions—which led to the formation of ferrite ghost lines. When the inclusions were not associated with high phosphorus, no ferrite envelopes appeared. We reproduce this paper on page 559.

The discussion was opened by Mr. H. Brearley, who said that, following upon an exchange of correspondence with Dr. Stead in 1912 on the subject of slag inclusions and sand inclusions, he, at Dr. Stead's suggestion, made a crucible steel experiment, putting slag into the billet. He arrived at a different conclusion from that of the author. Dr. Stead had said in his present paper that he drilled holes about 1 in. deep and $\frac{1}{8}$ in. in diameter in steel bars; powdered substances were put in the holes, and after compression the holes were closed by steel plugs, hammered down, and afterwards melted in an electric arc. Similar experiments were made by Dr. McCance. He (the speaker), did not think that line of experimenting would lead to conclusive results; ferrite bands would not be obtained, he thought, round slag of that kind. With cogged-down steel, the slag being run in with the metal, the ferrite bands formed round the inclusions. Dr. Stead had also said that in a forged steel, low in carbon, showing white streaks of ferrite enclosing non-metallic inclusions, if the streaks were due to phosphorus and the metal was heated to 1,200 deg. C., there would be no ferrite bands round the inclusions on cooling, due to the diffusion of the phosphorus in the surrounding metal. To this, he (the speaker), would remark that all ingots and blooms were turned into forgings, and the ferrite bands were found in those forgings; it would be strange, therefore, if Dr. Stead's statement in this respect were universally true.

Mr. J. H. Whiteley stated that he had read Dr. McCance's paper with great interest. With regard to the reagent for detecting sulphides in steel which he (the speaker) had devised, he found that the silver nitrate recommended by the author, did not diffuse so rapidly as the antimony sulphide; this was, no doubt, due to the gelatine. Some indication was possible with reference to the solubility of slag. He proceeded to say that he had found that as the carbon in the steel fell to below 0·1 per cent., the silicon concentration in the bath increased; he did not see how it was possible for the silicon to enter the slag through the action of 0·1 per cent. of carbon. It was difficult to detect silicates in the inclusions. It was no doubt the case, as Dr. Stead had stated, that when phosphorus and iron were irregularly distributed in iron or soft steel, on heating the metal to at least 1,200 deg. C. sufficiently long the phosphide became uniformly distributed.

Mr. Cosmo Johns said that he only proposed to discuss the paper by Dr. McCance. He desired to thank the author for making a most important contribution to our knowledge of a difficult subject. The paper was a record of carefully devised experiments, accurate observation and acute reasoning from the accepted principles of physical chemistry; characteristics which were often absent from papers communicated to technical societies. The occurrence of non-metallic substances in steel, though a matter of great importance to makers of the special steels, was not without interest to those who made the ordinary commercial steels. The much more searching character of the tests applied to the special steels gave these inclusions particular significance. In previous investigations the author had attributed these inclusions to reactions between entangled particles of slag and the manganese in the steel, but in the present paper had also brought forward important evidence to prove that dissolved ferrous oxide was the cause of certain of the inclusions. As some present might know, he (Mr. Johns) had for a considerable time held that the determining factor contributing to the formation of these inclusions was the dissolved iron oxide. As he had recorded recently* the ferrous oxide hypothesis explained all the facts and afforded a basis for further research. The entangled slag hypothesis, while explaining some occurrences, failed with others. For that reason he (Mr. Johns) had been led to discard the slag hypothesis, and felt satisfied that the presence of traces of ferrous oxide, soluble in liquid steel but insoluble or almost insoluble in solid steel, would, during and after the freezing of the liquid steel, react with the silicon, manganese and carbon present with the result of producing silicates or gaseous compounds. He (the speaker) had found himself unable to accept

* Jour. Soc. Chem. Industry, April 30, 1918.

the widely-held theory that silicon and manganese favoured the solubility of gases in steel. An explanation to be preferred was that in their presence solid reaction products were formed and the reaction between the concentrated ferrous oxide and the carbon was delayed until solidification had proceeded so far that blowholes did not appear, though carbon monoxide and dioxide would still be found and retained, either in solution in the steel or under high pressure. He concluded by again expressing his appreciation of the value of the paper, and trusted that the author would continue his investigation into the constitution of open-hearth slags, a field that had been much neglected.

Mr. E. H. Saniter, referring to Dr. Stead's paper, said he favoured Dr. Stead's original views with regard to non-metallic inclusions, and not his modified view as recorded above. If a decarburised area was found round a part of an artificial inclusion, it could not be assumed that this decarburised area was not present before the insertion of the inclusions. If in ghosts a non-metallic inclusion occurred in the centre of the decarburised area due to excess of phosphorus this was no proof that ferrite crystallised round the non-metallic inclusion. He further stated that he had read Dr. McCance's paper with great pleasure, but if he might be allowed a general criticism, it was to the effect that there was frequently an inclination to speak on broad lines on the subject of non-metallic inclusions, but the composition of steel must be taken into account. In steel having no silicon, the inclusions differed from those which occurred when a large amount of silicon was present. Dr. McCance's steel was acid steel. In basic steel, having 0·40 per cent. of manganese, and no silicon, if the top of the ingot were cut there would be found non-metallic inclusions which were principally oxide of iron; this was in solution, and only came out when the temperature fell. Dr. McCance at one part of his paper referred to the absence of segregation of non-metallic impurities in steel, and at other parts to the fact that these impurities do segregate, and to the evidence being favourable to the view that FeO was in solution in liquid steel. He (Mr. Saniter) preferred the two latter explanations to the first one. The author had also referred to the sulphur and manganese, but these must be considered in conjunction with the oxygen in the steel. It was well known that sulphur segregated to a greater degree than manganese. At temperatures very near the solidification point, combinations took place between the manganese and the sulphur. The author had further mentioned aluminium replacing manganese in removing the effect of sulphur in steel; but he (the speaker) would like to have a more significant reference upon the point than a casting containing 0·13 per cent. of sulphur. With regard, again, to Dr. McCance's statement with reference to the oxidation products of MnS, Mr. Saniter took it that the oxidation product was MnO. He was not able to detect a difference in sulphur in steel in the furnace and in the mould, and therefore the reaction must be very minute. The author's microphotographs, Figs. 21 to 24, did not show conclusive evidence that the inclusions were slag. When tapping acid steel, dead-melted, different samples were obtained from those taken during the middle of the boil at a time when the conditions were such as to cause the slag to be mixed with the steel.

Dr. Rosenhain, who followed, said that experiments carried out with foreign bodies introduced into steel in the solid state were inconclusive. In regard to the inclusion of fluorspar referred to by Dr. Stead, one possible explanation might be that for a body to act as centre for crystallisation it must be in an amorphous state, and fluorspar crystallised on the cube system. With reference to the paper by Dr. McCance, the latter spoke on the point of the mechanical effect of inclusions as though they were comparable to holes. If a metal having holes were strained, the hole had an elongated length and a reduced width, whilst if the hole were filled with a non-metallic substance there occurred no tension stress but a compression stress on the latter.

Dr. W. H. Hatfield found both Dr. Stead's and Dr. McCance's papers interesting. The latter had stated that all the evidence was favourable to the view that FeO was in solution in liquid steel, with this he (the speaker) agreed, But Dr. McCance went on to say that the addition of elements having a stronger affinity for oxygen than iron had, would reduce both the amount of FeO and the amount of gases in solution, and he (the speaker) could not follow that the addition would also reduce the gases in solution. Seeing that a considerable proportion of the gases in solution was hydrogen, in his (the speaker's) view they did not want to get rid of them. More gases had been found to evolve from sound steel than from badly-blown steel, and this clearly established the presence of the gases in the sound steel. In regard to slag, he had no hesitation in agreeing with Mr. Brearley, and in his experience, slag was found amongst the ferrite. Dr. McCance had stated that the inclusions were surrounded by an envelope of material high in phosphorus, and he (the speaker) would like to have further explanation on the point, since there might be ferrite areas round slag without the contributory phosphorus.

Professor C. A. Edwards agreed with Dr. Stead, but thought that the latter had perhaps not included all the possibilities which might have a bearing upon the case. He sketched on the blackboard his explanation of the way in which crystallisation proceeded on the manganese side and how ferrite followed the bands of crystals and how it grew on the manganese side.

Dr. Arnold, who followed, stated that he had studied the two papers by Dr. McCance and by Dr. Stead, and also the one by Mr. Kilby on "Defects in Steel Ingots," which was taken as read, with great interest. It was not possible to deal with them fully in the course of the discussion at the meeting. He agreed with Mr. Saniter that more details were wanted on some points. Dr. McCance had pointed out the influence of inclusions on the mechanical strength of steel. Unfortunately, the literature dealing with iron and steel problems was scattered among the proceedings of a number of Institutions. He (the speaker) recalled a paper which was read before the Institution of Naval Architects, on the subject of investigations made on a shaft for a large cruiser. He (the speaker) had found the sulphur content in the steel of that shaft to be rather high, namely 0·06 per cent., and, he added, when thinking of sulphur it should be considered micrographically, in terms of MnS. He also carried out 38 alternating tests on the steel of that shaft, which tests revealed better than any other tests the quality of the steel for the work to be done. He pointed out by a sketch on the blackboard the occurrences in longitudinal and transversal sections, also where there were laminations. In acid boiler plates there always were more or less laminations, and he showed their type. Phosphide of iron was in solid solution and it always occurred at the end; they had a broken end of pearlite. He also showed how sulphide of manganese occurred. He altogether agreed with Dr. Stead's views. Mr. Saniter's remark had rather astonished him (Dr. Arnold); that the sulphur in liquid steel was in the condition of FeS, he agreed, but that was before the manganese was added. It was interesting to have Mr. Saniter's view, but he dissented from it, and if Mr. Saniter would look up the work carried out at Sheffield University he would find that experiments had been made there to test that point. Invariably, and in spite of rapid cooling, they always got MnS. By altering the balance of manganese and sulphur, they could obtain mixed areas of brown FeS and grey MnS. Research work carried out by him, (the speaker) in conjunction with Mr. G. R. Bolsover seemed also to have escaped attention. When sulphide of manganese fell out from molten steel, it fell out at a temperature of about 1,350 deg. C. He showed how 12 FeMn later decomposed into 12 Fe + MnS and had proved that there remained in that way minute globules of perfectly clear MnS in the iron. Dr. Arnold also referred to Mr. Talbot's contribution of 1905, adding that when no aluminium was present there were large globules. He congratulated the three authors upon their contributions.

Mr. E. F. Law thought that Dr. Stead should let his conclusion stand as it was in the paper, and as is reported above; if he altered anything, however, he should delete, according to Mr. Law, the words "appeared to be," and write that "the evidence was conclusive . . ." He would have much to say in reference to Dr. McCance's paper, but would contribute it by correspondence; he would, however, ask Dr. McCance to make his present paper, Part I, to be concluded by a Part II which would include reference to Dr. Arnold's work on the mechanical properties of steel.

Sir Robert Hadfield, Bart., found that Dr. McCance's paper was an important one. He had referred to material which had cracked under a stress which experience had shown that it should have safely carried, and in this respect Sir Robert added that we were rather too apt to forget the carbon besides all the other elements present in steel. Sir Charles Parsons had read on the previous evening a most interesting paper on the formation of diamond, and in Sir Robert's opinion Sir Charles should be invited to read it also before the Iron and Steel Institute. Dr. McCance had alluded to the fact that the inclusions in small ingots were generally smaller in size than those of large ingots, and Sir Robert asked that if steel could be made with less inclusions why was it not so made and the fetish of large ingots dropped. It was not necessary to make one large ingot for cutting up later in the manufacturing process into a number of comparatively small blooms; a number of smaller ingots would meet the case. He thought that one of the reasons which had led to the success of crucible steel was connected with the relatively small size of the ingots cast in that steel. Since the war broke out he had made a considerable number of small ingots which had never been submitted to any forging or rolling action, not one of which had shown inclusions. If the steel was in the right condition, a good ingot could be obtained and there was no need to cause it to undergo forging or rolling. Economical working was a condition which had to be fulfilled, and at the present time especially, forges and rolling mills were wanted for other purposes. He congratulated the president on the enormous size of some shells he manufactured, and he expressed the hope that they were going to do a large amount of damage to the enemy. The president had been shown what we did in this country, and he would see that this country was not behind. A billet was not necessary for making a shell, it could be obtained from a sound blank. The steel-maker had a tendency to increase the size of his open-hearth furnace, and teemed the steel into a huge ladle, making one large ingot, instead of distributing it into comparatively small quantities, but this could be done, and small ingots made.

Mr. O. W. Ellis agreed with what Sir Robert Hadfield had said and had found, notably for the making of punches, that, starting from small ingots suitably heat-treated the life of the punches was better than in the case of those obtained from larger ingots which had been forged down; there was a lower content of phosphorus and sulphur.

Mr. G. Carrington stated that he had experienced difficulties from inclusions in commercial steels, and Sir Robert Hadfield's remarks in this respect were of great value; a large ingot worked down was not so suitable as a number of small ones. Mr. Saniter had said that the manganese in the steel did not come out until the steel had reached the point of solidification; in this respect Professor Arnold had given a good hypothesis of what happened. But he (the speaker) asked why, when bad iron was being obtained in the puddling furnace, endeavours were made to improve it by putting in the furnace a pig-iron high in manganese. In doing so, the manganese liquified the slag, it combined with the sulphur, and brought the latter out. He would like this question to be thoroughly thrashed out.

Mr. H. H. Ashdown thought that a useful purpose would be served by reference to the paper, dealing with an ingot which had bled, read before the Institution of Mechanical Engineers, by Professor Arnold, in 1915.*

Colonel N. T. Belaieff agreed with the negative part of Dr. Stead's conclusions. He (the speaker) remembered quite well Mr. Ziegler's first deductions and the important discussion which took place in support of them; later results showed that Mr. Ziegler was not entirely right. Inclusions had to be considered from the point of view of the broad

* See ENGINEERING, vol. c., pages 542, 550 and 575.

lines of the crystallisation of steel, for the same laws came into play, and research, he thought, would be justified on these lines. Dr. McCance's paper was a very important one in that it formed a link between purely scientific research work and work of a decidedly practical nature. Too much emphasis should not be laid on the percentage of the inclusions, for what was also of great importance was the structure of the inclusions and the steel could be treated so as to vary their structure, making this spherical or of a rounded shape.

Dr. McCance and Dr. Stead intimated that they would reply to the discussion by correspondence. On the motion of the chairman, they were cordially thanked for their communications.

The Effect of Cold-Work on the Divorce of Pearlite.

The first paper taken at the meeting on Friday afternoon, May 3, was the one having the above title, by Mr. J. H. Whiteley, who read it in abstract. He showed, by annealing drillings and other cold-worked samples of pearlite steels for a short time below the critical point, 690 deg. C., that the values for the combined carbon as given by the Eggertz colour test could be considerably raised. The effect of annealing such cold-worked steels was to cause the carbide laminæ of the pearlite to break up quickly into a series of spheroids. The change began at about 500 deg. C. and proceeded with increasing rapidity as the temperature was raised. On annealing at 680 deg. C. this pearlite-divorce could be completed in less than 2 hours even in a eutectoid steel when the laminæ were very thin; very coarse pearlite required about 4 hours' heating. The condition obtained by annealing at 650 deg. C. after cold-working the metal, resembled in several respects that obtained by quenching and tempering for about 2 hours at the same temperature. We reproduce Mr. Whiteley's paper on page 562.

The Effects of Cold-Working on the Elastic Properties of Steel.

The next paper was on the "Effects of Cold-Working on the Elastic Properties of Steel," by Mr. J. A. Van den Broek, Michigan. It was read in abstract by the secretary. In this, the author described his tests, and found that the cold-stretching of steel did not lower its elastic limit in compression; the effects on elasticity of cold-twisting were proportional to the distance between the axes; the effects of cold-working on the elastic properties were probably a function of the strains and independent of the stresses involved in the cold-working process—all of which effects were reviewed in detail by the author.

The two papers were taken together for discussion. This was opened by Dr. Rosenhain, who stated that the two papers gave a rather diverse aspect of the effects of cold-working. Mr. Whiteley's observations as to the divorce of pearlite were borne out by the experiments carried out by him (Dr. Rosenhain), at Teddington; as for the explanation, that remained an open question. The power of readjustment was a question of mobility of the molecules or of atomic mobility. In strained metal ferrite was not entirely crystallised, and could dissolve other constituents to a certain extent. As regards Mr. Van den Broek's paper, he (Dr. Rosenhain) could not refrain from owning to a certain amount of scepticism concerning the experiments made, and found that apparatus of a much greater sensitiveness than those used by the author were required. The author had referred to the data obtained by Bauschinger; an opposite opinion could be put upon Bauschinger's observations. Berthelot's work had confirmed Bauschinger's view on the elastic properties of steel, and a great deal more work would have to be carried out to shake that view, much as he (Dr. Rosenhain) would like to see it shaken. In this respect, he repeated that much more delicate measurements would be required than those arrived at by the author. For this reason, the various conclusions given by the latter were partly invalidated. The raising of the elastic limit by cold-working could be most useful; but when the elastic limit was raised in that way, if the metal were then subjected to alternating stresses, the higher elastic limit became a fictitious property, a reservation which, he thought, it was necessary to make.

Dr. C. H. Desch said it was a pity that Colonel Belaieff's paper on "Damascene Steel" was not going to be taken in conjunction with the two which had just been read, as it dealt with a similar question. A full discussion on the three would be found useful, and as Colonel Belaieff had said, his investigations might have a practical application. Dr. Desch added that a further possible explanation of the points which had been reviewed was the most likely one of surface tension. Surface tension forces could be brought to such a condition that they could have full play.

The chairman announced that the authors would reply to the discussion in writing, and asked for a cordial vote of thanks to them, which was responded to.

A Cause of Failure in Boiler Plates.

The next paper taken was entitled "A Cause of Failure in Boiler Plates," by Dr. Rosenhain and Mr. D. Hanson. It was read in abstract by the latter. The paper dealt with a failure which occurred in the last stage of the manufacture of a boiler plate 1¼ in. thick; the plate cracked during the straightening of the edges after the bending operations had been completed. Bending had been carried out in stages, cold, the plate being subjected to intermediate annealings between the various stages. The plate was bent to a semicircle, and from one edge it cracked along the crown on the outer surface, as illustrated in the paper, which also gives the chemical analysis of the steel and the physical tests made. The figures obtained showed that the steel was in an abnormally bad condition, presumably as the result of some treatment—thermal, mechanical, or both—which it had received during manufacture. The paper then gave different micrographs of the metal and the conclusions arrived at from these. We propose to reproduce it in a later issue.

Mr. J. Ainsworth, who opened the discussion, asked whether the failure was attributable to the actual manufacture of the plate, or to the bending operation.

Mr. C. H. Ridsdale asked whether the carbonless bands referred to by the authors occurred just outside the bend or in the mass of the plate. He confessed ignorance as to crystallisation resulting from deformation at a low temperature, but he had not had the opportunity of following the matter up experimentally, and the reading of the paper had confirmed him generally in the opinion he had formed that the whole detrimental effect due to repeated annealing was that it caused too great a decarburisation. He also asked in what way deformation at low temperatures facilitated crystal growth on subsequent reheating. In his (the speaker's) paper contributed in 1898, on the brittleness of soft steel, he stated he had worked upon an acid open-hearth steel boiler plate as one of several types, and had therein described one occurrence as blue-heat brittleness; all steels would develop that blue-heat brittleness, and some gained susceptibility to it if they were first heated, or soaked for a short time in a temperature of about 1,000 deg. C. But he was still inclined to think that repeated annealings predisposed steel to be subject to brittleness at low temperatures.

Dr. Stead said that he was greatly interested in the paper. The wonders connected with ferrite were infinite; he had been collecting notes to present to the Institute a paper on ferrite and had found out a large amount of wonderful points, but many other wonderful ones were still unknown. He was trying, among other matters, to determine the orientation of ferrite crystals, for different results were obtained if the material were cut across or along the crystal, or to an angle of 45 deg. with it. Sometimes one could have a large ferrite crystal in the centre of the banded structure, the orientation being such that the material would give a good test. Once a cleavage started then all the crystal would snap. He would discuss the various points in his paper. He had seen the authors' paper in manuscript form and had found the same occurrence in the case of drawn wire, which would be brittle at certain parts where there were large ferrite crystals, whilst at other parts and over whole yards in length the wire would not be brittle at all, there being no great difference in the size of the crystals; the reason was that the brittleness was due to the cleavage in the crystals coming into line. There still, however, occurred a number of mysterious fractures, and the authors' paper had explained some.

Mr. H. H. Ashdown, referring to Dr. Stead's Plate II, here asked whether in the banded structure he got rediffusion of the carbon, and if the diffusion was due to excess of heating of the plate immediately before rolling. On rolling the large crystals were rolled down. Dr. Stead replied that he would deal with the point in writing.

Dr. W. H. Hatfield agreed with Dr. Stead concerning the occurrence of mysterious fractures. Dr. Stead had referred to brittle wire in which the crystal size did not show disparity. Under the microscope, he (the speaker) had found crystals larger than others and he had also found steel having quite large crystals to give a high impact value. The authors had said that cold-working and annealing at low temperatures produced large crystals and failure under impact tests. Had they examined other similar boiler plates which did not crack? He (the speaker) would have anticipated that impact tests would also have been carried out on a second, otherwise sound plate. He also asked what the fracture was like and whether a photograph of the fracture could be furnished. Were there local defects of any kind? It was conceivable that the plate was in a bad condition when it was given to the people who had to do the bending. The authors had said that they had used an impact test, for although it was recognised that the conditions under which failure occurred in a boiler plate possessed no apparent resemblance to those of an impact test, yet experience had repeatedly shown that materials which gave a low figure under an impact test were liable to fail under apparently static conditions. He (the speaker) thought the authors should prove that statement; the point that material failed "under static conditions" was an important one to all constructors and engineers, and he asked what reasons the authors had to bring forth that statement.

Mr. E. H. Saniter agreed as a whole with the authors' explanation of the trouble in boiler plates, and their table II, which gave the resistance to impact of specimens taken from the boiler plate No. 1 after it had undergone a number of different treatments, was most conclusive evidence that with a certain amount of cold-working there was a connection between failure and brittleness. Independently of anything advanced by the authors, there were two facts, namely, the enormous advantage of normalising boiler plates at suitable temperatures and the making of boiler plates of steel not containing this banded structure.

Dr. Rosenhain, in replying briefly to the discussion, said that the question as to what share in the case was attributable to the manufacture of the plate and what to the maker of the boiler, was obvious, particularly as regarded the boiler plate No. 1. He could not reply in the present instance as to grain growth, the point having been well thrashed out in other papers. The presence of large ferrite crystals having a different orientation explained why the large ferrite crystals were more responsible for fractures than the small. If the crystals were small and well supported there was not much trouble. He could not answer the question as to diffusion of the carbon, but doubted whether diffusion occurred. With reference to Dr. Hatfield's remarks, he also had seen much larger crystals where at first sight there was no disparity in their size, and had examined many test-pieces of plates that had not failed and were free from the defects which the cracked plate had shown. The impact figures of the second plate given in the paper were not as low as might be expected from the lesser crystals. The crack had been carefully examined, but there was nothing suggestive about it.

Effect of Mass on Heat Treatment.

The last paper taken at the meeting on the afternoon of Friday, the 3rd inst., was on the "Effect of Mass on Heat Treatment," by Mr. E. F.

COAL-HANDLING PLANT AT THE SALTLEY GAS WORKS, BIRMINGHAM.

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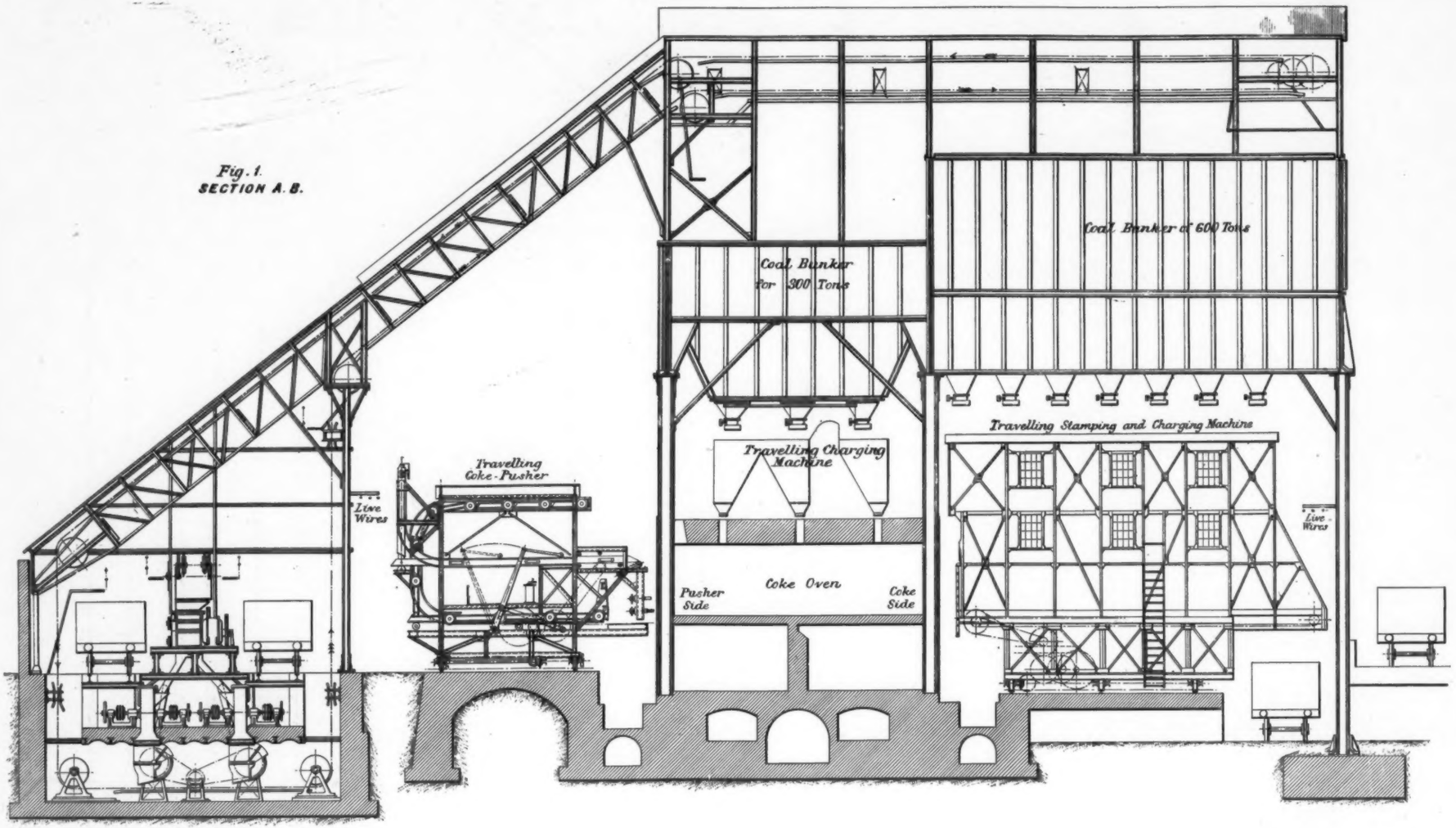
(*For Description, see Page* 541.)



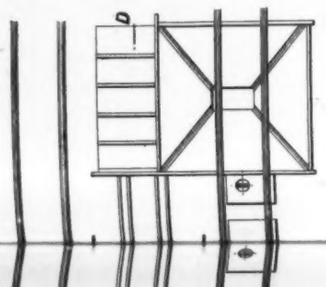


Fig. 2. PLAN

Fig. 2. PLAN

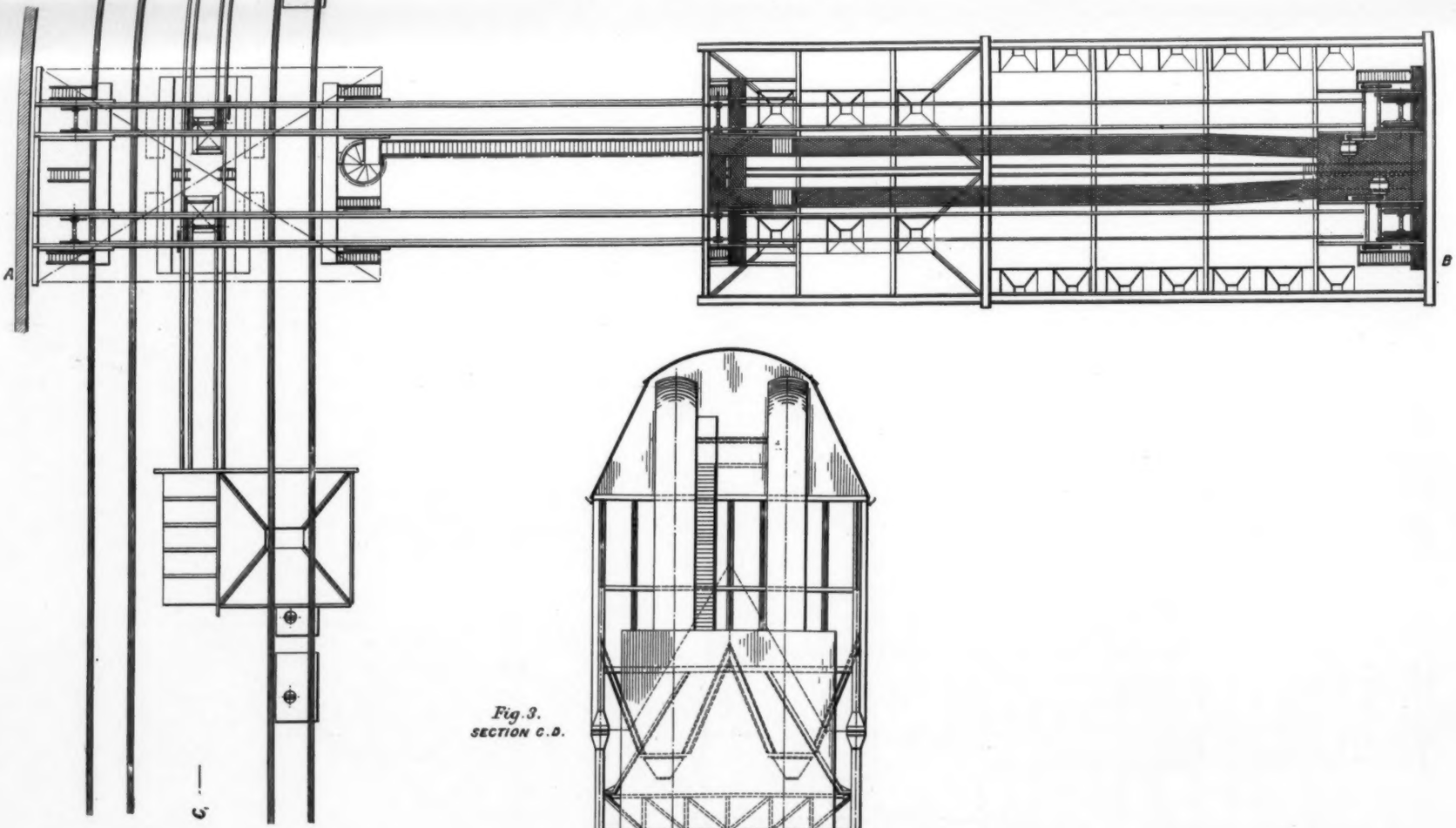
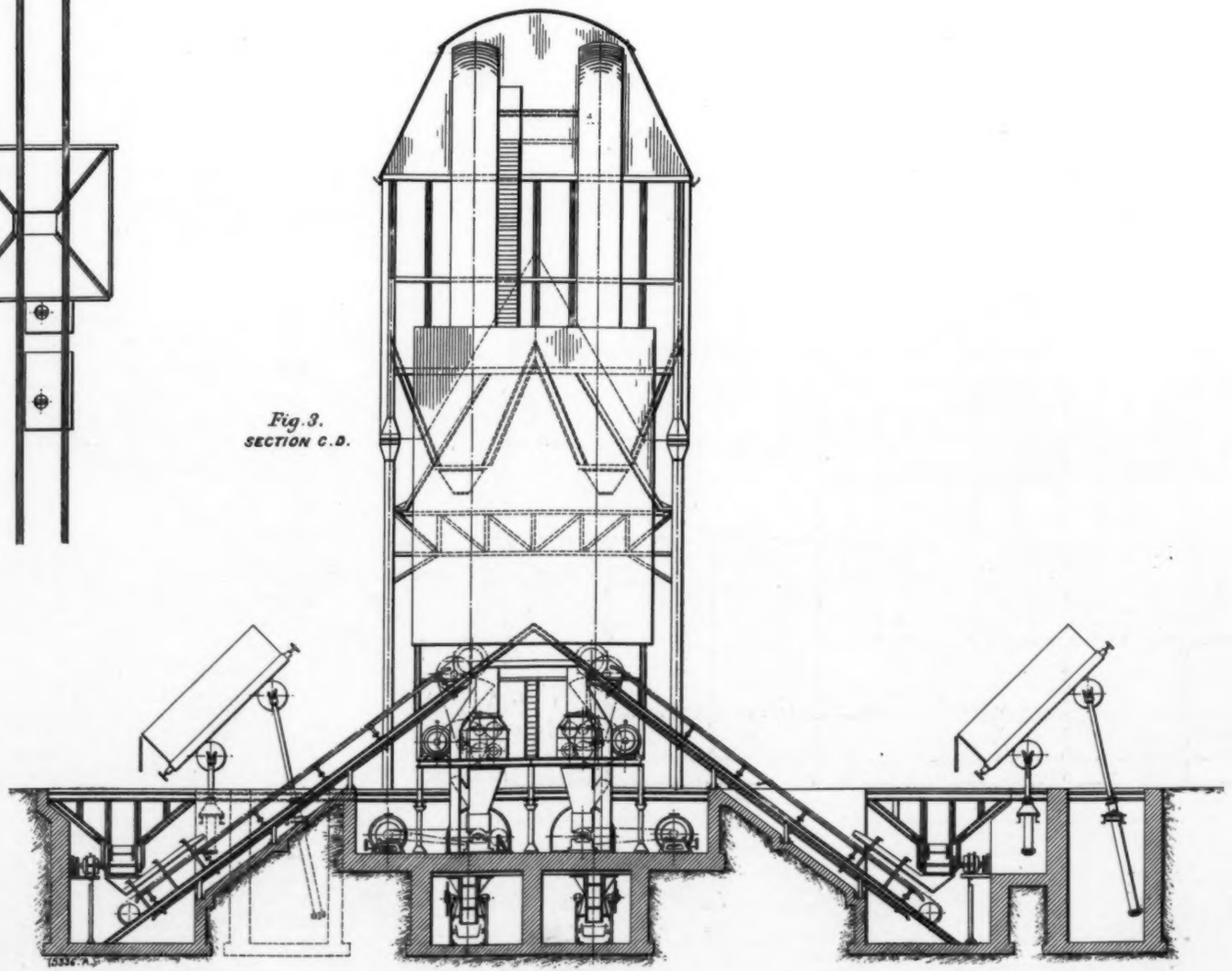


Fig. 3.
SECTION C.D.



Law, who read it in abstract. Mr. Law stated that the difficulties met with in the heat treatment of large masses of steel lie not in the lack of knowledge concerning the properties of the steel, but rather in the practical application of that knowledge. In his investigations, a 25-in. square ingot, 10 ft. in length, and weighing nearly 10 tons, was cogged down to 18 in. square, and was then cut into 18-in. lengths, thus giving a number of 18-in. cubes, each weighing approximately 14½ cwt. Only those cubes representing the soundest part of the ingot were employed in the experiments. The paper gave the chemical analyses of the steel, the heating and cooling curves, the mechanical tests and micrographs of the steel after different treatments.

Mr. Cosmo Johns found the author's curves most interesting. He objected to the bringing in of the atomic structure, and felt it a duty to add that there was no warrant to say that the atomic structure played any part in steel.

Dr. McCance questioned some of the author's explanations as to the changes which occurred at certain temperatures, and his evolution of heat in some instances seemed too great to be accounted for by the explanations he had given; convection came in, and had to be accounted for.

Sir Robert Hadfield suggested that the Fahrenheit scale should be dropped. He added that he was pursuing his investigations on the spontaneous generation of heat and hoped shortly to present a paper covering hard material. The author had referred at the close of his own paper to the property of hardness. He (Sir Robert) recalled that some time ago he had offered a prize on the subject of hardness determination; so far only two replies had been received, and he would like a British citizen to gain it. He had only just received information from Mr. Shaw, to whom we were indebted for the scleroscope, saying that he had found the relation between the ball test and the scleroscope test; Mr. Shaw added that he would send full particulars later. If Mr. Shaw succeeded in determining super-hardness, added Sir Robert, we should be greatly indebted to him. Sir Robert was glad that Mr. Law had referred to hardness in his paper.

Mr. Heaven found the details given in the paper of great value to steel users; they would have a great bearing in helping to solve some difficulties which occurred in the shop in regard to hardness. He would ask whether the author had any information to give as to the bearing of his results on the cracking of steel, for he (the speaker) had met with trouble in the hardening of a form cutter; this cracked, or failed rapidly. He had tried all kinds of treatment. The tool was quenched in water, then in oil, and allowed to cool down; he would like to know whether a certain lag was induced by the later cooling in oil.

Mr. H. H. Ashdown also suggested replacing the Fahrenheit scale by the Centigrade. He agreed in the main with the author, but the latter had not altogether satisfied the title to his paper, for this dealt with mass only as far as comparison with current laboratory work went. He confirmed that a large amount of good work was done at Woolwich, this was always secret service work; it would, however, interest the members to know that records were taken of the heat treatment operations of marine gun forgings.

Mr. E. H. Saniter found that the paper contained many interesting points, particularly those dealing with the evolution of heat at low temperatures. If a small piece of steel were taken and heated to 250 deg. C. interesting results would be found; in a great many instances the steel was in a state of stress, and by reheating the small pieces to a certain temperature, that stress was got rid of. The evolution of heat was perhaps due to that state of stress.

Mr. E. F. Law said that he had carried out a vast number of experiments, the records of which were not included in the paper so as not to confuse the issue. In regard to the temperature scales, this was a difficult matter to deal with; the Fahrenheit was still used in most works of this country and he had put in both the Fahrenheit and the Centigrade figures. He was glad to hear Sir Robert Hadfield's remarks on hardness. He (the author) thought the occurrences with his cubes were comparable to those on heavy forgings; if he had carried out work on gun or armour-plate forgings he would not have been able to make his records public. What he wanted to obtain were data on fixed and uniform sizes. He added that he would reply in full to the discussion by correspondence.

On the motion of the chairman, the author was awarded a hearty vote of thanks for his contribution.

The remaining papers on the list were taken as read.

The usual vote of thanks to the Institution of Civil Engineers for the loan of their hall, and to the chairman, terminated the proceedings.

STEAM AND POWER PLANT FOR CHEMICAL WORKS.

JUST now, when a large number of chemical works, many of great size, are being erected in different parts of the country, it is of interest to consider briefly what are the conditions to be met as regards steam and power supply in such works. These conditions are largely different from those existing in an ordinary engineering works or the general run of mills and factories. In many instances consulting power engineers have been called in to design the steam and power plant for chemical works with disastrous results, due entirely to ignorance of the special conditions to be met.

The great point is this, that in a chemical works, in which term may be included bleaching, dyeing and similar works, immense quantities of steam are required for process heating, including boiling, evaporating, distilling, drying, and so on; and the amount of steam required for generating power is insignificant—usually about 20 per cent. or even less of the whole. Further, this heating steam is required at a low pressure, say, 30 lb. per square inch, and with only enough superheat to ensure its reaching the point of application furthest from the boilers in a dry state. High pressure steam in a chemical works is a continual source of trouble and danger. In particular, it is not suitable for use in jacketed vessels, or in leaden vessels or coils.

In some cases of distillation a temperature of 150° C. to 170° C. is required, and if steam-heating is necessary in such cases a small high pressure steam main will have to be run to the plants in question from the power boiler house. It increases the danger of explosion due to the corrosion of steam pipes and vessels by acids, and it adds to the trouble with leaky joints.

High superheat is also very undesirable, involving much trouble with valve seatings, and, more serious still, in some cases resulting in the oxidation or charring of substances which come into contact with coils containing steam at a very high temperature. From the thermal point of view, low pressure, low superheat steam is very nearly as efficient as high-pressure high superheat steam. For instance, one pound of steam at 125 lb. gauge pressure and 150 deg. superheat contains about 1,271 British thermal units, total heat reckoned from water at 32 deg., whereas a pound of steam at 30 lb. gauge pressure and 25 deg. F. superheat contains about 1,178 British thermal units on the same basis. The latter figure is nearly 93 per cent. of the former. Taking into account the reduced wear and tear on boilers, pipe ranges, and plant generally with low-pressure steam, there is no question but that it is by far the best and most economical system to use.

With regard to boilers, it must be constantly borne in mind that the steam load of a chemical works is an extremely fluctuating one. A plant which has been temporarily shut down for repairs or other reasons, may be started up and steam turned full on to a number of vessels, thus increasing the load by perhaps 20,000 lb. per hour within a few minutes. The reduction of load when steam is shut off from a plant or a number of vessels may be equally sudden. A type of boiler with a very large steam reserve, is, therefore, necessary, and there is no better boiler for the purpose than the Lancashire. Water-tube boilers are not suitable unless a very large boiler plant in proportion to the average load is put in.

Coming to the question of prime movers, steam plant is, of course, selected since the exhaust steam can be used for heating, as well as live steam. A few boilers working at moderately-high pressure are put in to supply the engines only, which should exhaust at 30-lb. back pressure, the steam passing through a superheater into the low-pressure system. In this way, power is obtained practically free of cost, since the steam is wanted anyway, and only a small percentage of heat is taken away in passing through the engines. The high-pressure boilers can be put down close to the power house, and away from the manufacturing sheds, if electrical transmission is used, but it is essential in all cases to place the main low-pressure boiler house, which will be four or five times as large as the high-pressure installation, as centrally as possible among the sheds where the steam is used.

In choosing the type of steam engine (for turbines have little to recommend them in this particular case), the only relevant factors are: first, reliability, second, low cost of maintenance; and, third, low capital cost. *The consumption of steam per horse-power hour is of no consequence.* In some chemical works, especially where explosive or highly-inflammable substances are dealt with, it is preferable to drive the shafting and machinery with simple non-condensing steam engines, more particularly where the exhaust steam can conveniently be utilised close at hand. This is a system which would surprise a modern power engineer, but then he is absolutely unused to getting his steam for almost nothing. It is a thoroughly sound economical system in many cases.

In other works, where the conditions are more favourable to electric driving, a central power station will be provided where current will be generated by steam engines fulfilling the requirements mentioned above, and the process plants will be driven by motors either on the group system, with a number of machines belt-driven from a motor-driven line shaft, or, in the case of heavier machines, by individual motors.

Many reasons indicate direct current as the best for chemical works. If the works are very extensive or scattered, high tension alternating current may well be generated for distributing purposes, and passed through rotary converters, so that the current in the process sheds is direct current.

The first reason against alternating current in chemical works relates to danger from shock. The sheds are generally full of steam, the floors and platforms are wet—in other words, ideal conditions exist for earthing the men, and ensuring the maximum shock on accidental contact with a live wire or fitting, and owing to rough handling and corrosion from acid fumes, bare live wires or fittings are not uncommon. Under such conditions 200 volts alternating current is usually fatal, and 440 volts always so, whereas direct current is much less dangerous. Even with direct current, it is better not to exceed 220 volts in a chemical works.

Other reasons in favour of direct current motors are their large starting torque, ability to run at variable speeds, large safe overload capacity, and simple starting gear—all very valuable points in a chemical works where heavy agitators have to be started up in viscous liquors, and sometimes run at different speeds at various stages of a process. The squirrel cage induction motor is deficient in all these respects, and wound rotor motors are little better. The old drawback of the direct-current motor—commutation trouble—has practically disappeared in modern interpole machines made by first-class makers. Any possible danger of fire or explosion from sparking can be obviated by the use of enclosed pipe-ventilated motors, a type which is necessitated in any case by the risk of corrosion by fumes and damp.

A final advantage of direct current is that it is often useful for electrolytic work. There are very few modern chemical works where some electrolytic process or other is not used, and further applications of this method are constantly being worked out.

COAL-HANDLING PLANT AT THE SALTLEY GAS-WORKS.

By GEORGE FREDERICK ZIMMER, A.M.Inst.C.E.

ON the Continent by-product ovens have been pressed into service for the manufacture of illuminating gas for town lighting for quite a considerable time. To judge from the recent achievements in this direction at the Saltley Works of the Gas Department of the City of Birmingham there are unmistakable signs

COAL-HANDLING PLANT AT THE SALTLEY GAS WORKS, BIRMINGHAM.

CONSTRUCTED BY MESSRS. BABCOCK AND WILCOX, LIMITED, ENGINEERS, LONDON.

Fig. 4. The Upper Terminals of the Two Tray Conveyors.

Fig. 5. End Door Coal Truck on One of the Tips and Ascending and Descending Tray Conveyors.

COAL-HANDLING PLANT; SALTLEY GAS WORKS.

CONSTRUCTED BY MESSRS. BABCOCK AND WILCOX, LIMITED, ENGINEERS, LONDON.

FIG. 6. END DOOR COAL TRUCK ON TIP.

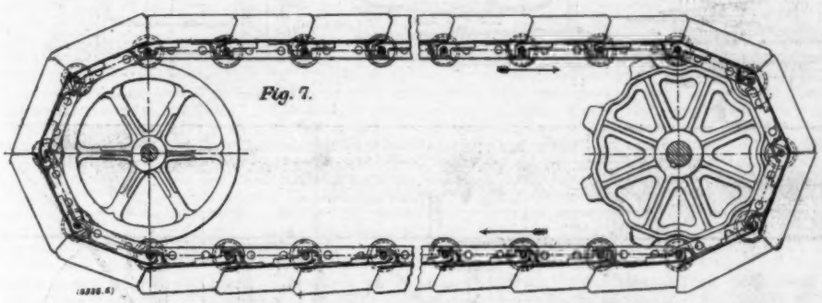


Fig. 7.

that in this country also it has been realised that gas from chamber ovens is not only suitable for steam production and the generation of electricity, but that it can equally well be used for town lighting. Hitherto the stumbling-block to the fuller use of this gas has been its varying composition and its low illuminating power.

A most interesting paper on coke ovens, which also pointed out some of the reasons for the delay in the introduction of this method of carbonising, was read some time ago by Mr. W. Chaney, the Engineer and Manager of the Saltley Gas Works, before the Institute of Gas Engineers, and in this paper he dealt particularly with the aspect of coke and gas production by this system.

The remodelling of the carbonising plant of the Birmingham Gas Works has been for some time under consideration by the corporation, and bearing the brisk demand for furnace coke in mind, their choice fell upon coke ovens, although in the case of furnace coke the main aim is a big yield of coke of definite characteristics, while for gas works the yield of gas is the principal consideration. It has, however, been proved by the inspection of some of the Continental installations that a construction to meet all requirements is possible, and the management of the Birmingham Gas Department determined, therefore, to recommend the adoption of Kopper's chamber ovens of such a design that they can serve the dual purpose of justifying the demands of the ironmaster and those of the Home Office. In due course a battery of 12 such ovens, with the necessary accessories, was installed at Saltley, in October, 1914, and recently the Gas Committee increased the plant to 66 ovens in all; these ovens are heated by outside producers of the Mond gas type with ammonia recovery. Although the Kopper coke ovens have been used for years in this country for metallurgical coke, they have not previously been used for town lighting.

The coal-handling plant, which is the main subject of the present article, was designed as a whole and supplied in 1914 by Messrs. Babcock and Wilcox, for the purpose of delivering fine coal to the Kopper chamber ovens for the production of metallurgical coke, and also for the production of gas, and when taking but a casual survey of the illustrations published in the present issue one is at once impressed by the foresight displayed in its conception, in providing against breakdowns and their consequences. Immunity from such disasters should be a *sine qua non* in all establishments upon which we depend for light and heat. As far as the coal-handling plant of the Saltley works is concerned it fully meets these conditions in every way, since the mechanical equipments are in duplicate, while as regards the feeding of the chamber ovens, provision has been made for two alternative ways of accomplishing this work.

Briefly described, the handling plant, as shown in Figs. 1, 2, and 3, Plate LI, consists of two coal tips with track hoppers under, from each of which the coal can be raised by an inclined tray conveyor to such a height that it can be fed by gravity successively into two coal breakers and then into four disintegrators, and, finally to the two gravity bucket elevators. These elevators ascend, as indicated in Fig. 1, first perpendicularly, then at an incline, and eventually travel on a horizontal path across the two bunkers, into which they drop their load, and from where the empty strand returns practically parallel to the loaded strand, and thence to the feed-end again.

The two inclined tray conveyors mentioned above lean towards each other and nearly meet at their upper terminals. A good idea of them may be gained from Fig. 4, page 542, which is a bird's-eye view of the upper terminals, and Fig. 5, on the same page, which is a view taken from the ground level and also shows the perpendicular portion of the gravity bucket conveyors. The plane in which these tray conveyors lie is parallel with the tracks on which the coal arrives, while the two gravity bucket conveyors travel side by side in planes at right angles to the former.

The coal to be used at this installation may differ very materially in size and may range from run-of-mine coal down to the smallest washed "slack," and as it is imperative that the coal supplied to the bunkers for feeding into the charging machines, and eventually into the ovens, should be a fine powder, whatever the size may be at its delivery, it has, if coarser than powder, to be reduced. This entailed the installation of coal breakers to reduce the large coal to nut size, also disintegrators to reduce the latter to such a degree of fineness that it can be consolidated into cakes by the stamping machine prior to insertion into the coke ovens. Owing to the variety in size of the coal used in the plant it became necessary to arrange for a series of by-pass shoots in order to cut out the coal breaker if nut coal is received, or both breakers and disintegrators, if "slack" or coal dust has to be handled. Thus the available grinding plant can be utilised whenever and to whatever extent is warranted by the size of the coal delivered. We thus see that for lump coal both crushers and disintegrators are used; for coal the size of nuts or smaller, the breaker is by-passed by means of a deflecting valve fitted under the terminal of the tray conveyor, whereby the coal is delivered to the feed of the disintegrators; while for very small "slack," which need not pass through either of these grinding or crushing machines, a by-pass shoot and deflecting valve are provided, by means of which the material is delivered direct from the tray conveyor to the special filling device of the gravity bucket conveyor.

A capacity of 80 tons per hour of powdered coal is provided for on each of the duplicate plants, and either side is so designed that it can work quite independently of the other and deliver its load in a continuous stream into the overhead bunkers which serve the charging machines. Thus either side of the plant constitutes a complete unit in itself, quite independent of the other.

Each unit consists of:—

1. Coal-tipping device over a track hopper.
2. Tray conveyor for the coal as received.
3. Coal breaker.
4. Disintegrators.
5. Gravity bucket conveyor for the pulverised coal, which feeds into
6. The overhead bunkers, which latter constitute the only part which the two plants have in common.

We will now describe the six items which constitute a unit of a plant, in the order mentioned.

1. *Tipping Device and Track Hopper.*—End-door wagons are employed to bring the coal to the works, they arrive on the same line of rails for both plants, as it is not intended that both units should be in operation simultaneously at any time. A turntable has been installed on the incoming line in order that any truck which may arrive otherwise than with the end door foremost can be turned round before proceeding to the discharging point. Photographic views, Figs. 5 and 6, on the opposite and present pages, show one truck on the tip. The tips employed for emptying the trucks over each of the two track hoppers are of the double-ram type, they work under a water pressure of 600 lb. to 800 lb. per square inch; the forward ram is in a stationary position and has only a lift sufficiently great to raise the buffers at the front end of the truck clear of the rails, as with the ordinary single-ram tips the buffers may touch the rails before the truck has been raised to an angle sufficient for all the coal to slide out, without assistance by hand. The rear ram has a long throw and is of the swivel type, mounted on trunnions, through which the hydraulic mains enter and leave. This ram lifts the trucks to an angle of at least 50 deg. to ensure, as far as possible, a clean delivery of any class of coal used. Each ram is provided with independent control valves, so that the angle of the truck can be adjusted to a nicety to suit the prevailing conditions. The track hopper will hold 15 tons. The coal is delivered through an adjustable valve at the base of the receiving or track hopper (see Fig. 1) on to a jigging feed supplying the coal in a uniform stream to the receiving terminal of the tray-conveyor. An electric capstan is provided for hauling the wagons from the line to the tipping point and for conveying the empties to the siding for the returning trucks.

2. *Tray Conveyor.*—This is about 48 ft. long from centre to centre, and is of the Babcock and Wilcox standard over-end delivery type (see Fig. 7); it takes the coal as received from the jigger at the base of the track hopper and elevates it to the breaking plant. Fig. 5 shows the ascending strand of one, and the descending strand of the other of these conveyors. The feeding device is electrically driven from an independent motor, with reducing gear operating through eccentric rods. The whole of the jigger can be regulated to suit any class of coal being dealt with, different adjustments being required for lump as against slack. The conveyor is sprocket driven and operated by a Brampton chain from the same motor which actuates the coal breaker. The short length of tray conveyor, as shown in Fig. 7, is 30 in. wide and 12 in. pitch. The chains, both for the tray and gravity bucket conveyors, Figs. 8 to 11, page 544, are of the Babcock and Wilcox double-link bushed type, each link being made of flat steel, while steel stud rivets form distance-pieces for the pairs of links. The driving gear is of the sprocket type, the sprockets being of cast steel as well as the driving gear, excepting the pinion, which is mild steel, and engages directly with the distance-pieces between the chain links.

3. *Coal Breaker.*—This is of the standard Babcock

COAL-HANDLING PLANT AT THE SALTLEY GAS WORKS, BIRMINGHAM.

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Fig. 8.

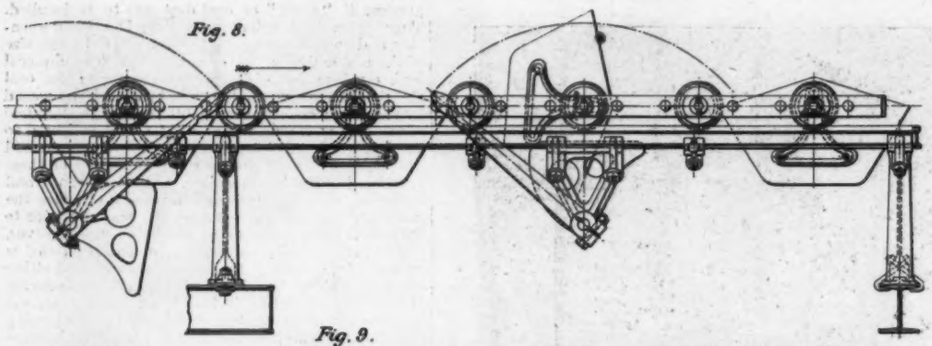


Fig. 10.

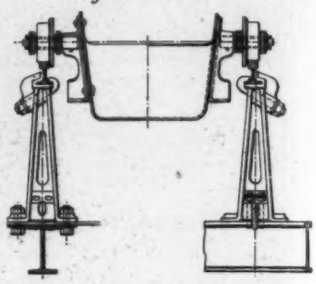


Fig. 9.

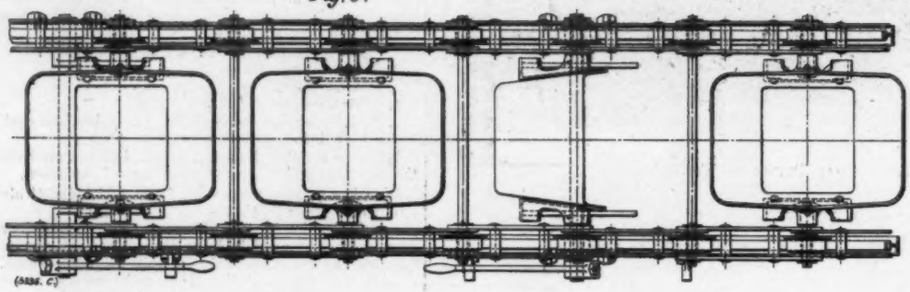


Fig. 11.

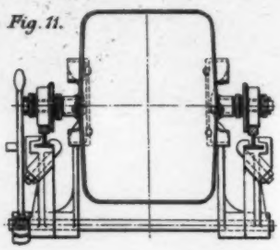


Fig. 12.

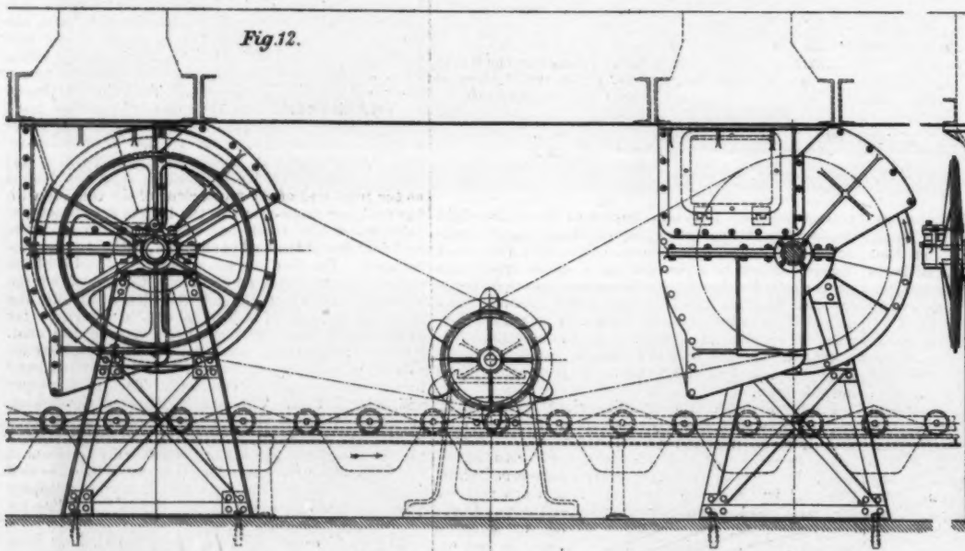


Fig. 14.

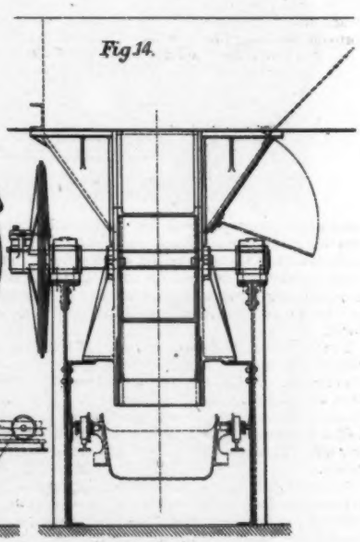


Fig. 13.

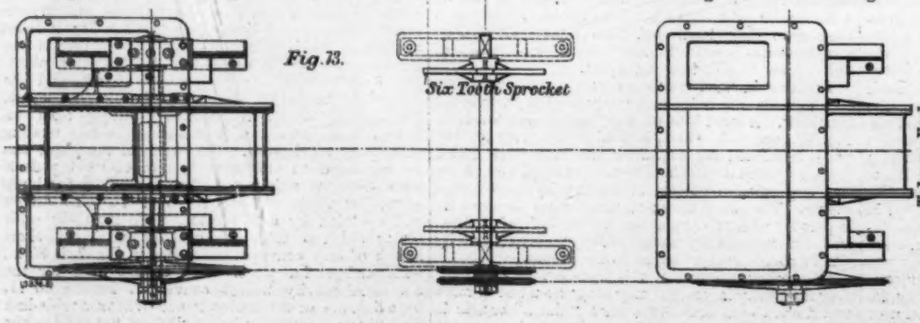
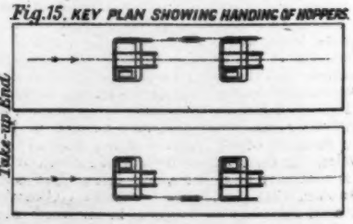


Fig. 15. KEY PLAN SHOWING HANDING OF HOPPERS.



and Wilcox four-roll type, having a cast-iron frame, mild steel shafts and manganese steel claws. It is driven by a 45 h.p. motor through cast-iron spur gearing, and has a capacity of 80 tons per hour; it is capable of breaking "run-of-mine" coal to a size which will pass through a ring 2 in. in diameter.

The motors operating the jigger, and also that for the breaker and tray conveyor, are interlocked so that the jigger feed cannot be started up until the breaker and tray conveyor have been put in operation, thus rendering this part of the plant fool-proof.

4. *Disintegrators.*—Two disintegrators of the "Carr" type are employed in each of the two plants, as each machine is only capable of reducing 40 tons of small nut coal per hour to a powdered condition. Two of these are shown in Fig. 20, page 550; in the further one the covering has been removed. They were manufactured by Messrs. Pratchitt Brothers, Denton Ironworks, Carlisle, and consist of two concentric cages which revolve in opposite directions to each other; the coal is fed in at the centre or into the inner cage

COAL-HANDLING PLANT AT THE SALTLEY GAS WORKS, BIRMINGHAM.

CONSTRUCTED BY MESSRS. BABCOCK AND WILCOX, LIMITED, ENGINEERS, LONDON.

Fig. 16.

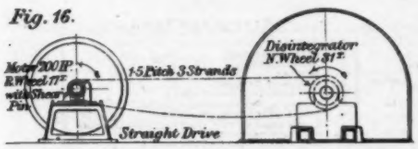


Fig. 17.

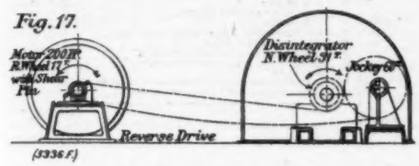


Fig. 18.

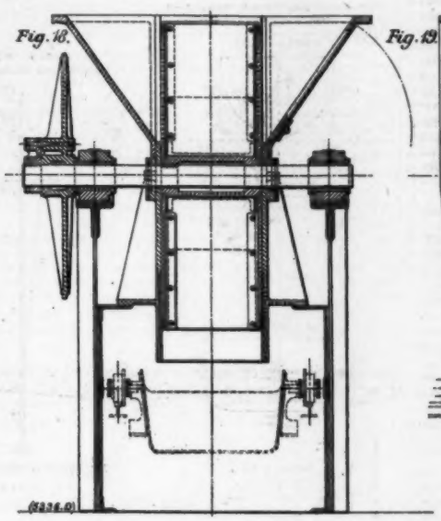
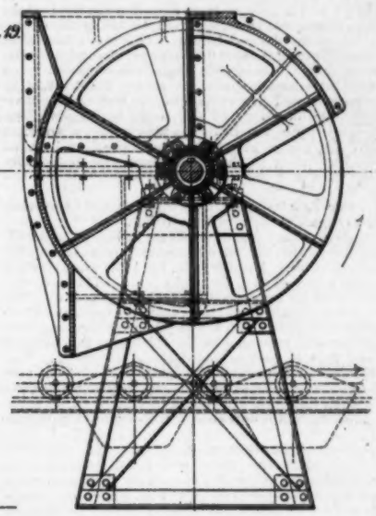


Fig. 19.



and centrifugal force causes it to pass between the bars of the cages, which speedily reduce it to powder. This pair of disintegrators is driven from a countershaft direct-coupled by a flexible coupling to a 200-h.p. motor.

Each cage of each of the disintegrators is actuated by a separate drive (see Figs. 16 and 17 annexed), consisting of three strands of 1½-in. pitch bush roller chains, running in parallel, and at a speed of over 1,500 ft. per minute. These drives are completely enclosed in dust and oiltight mild steel casings fitted with oil bath and pump to ensure continuous lubrication, and were supplied by Messrs. Hans Renolds, Limited. As the cages revolve in opposite directions, it was necessary that one drive should be of the open type and the other (in order to reverse the direction of rotation) had to be geared into the outside of the chain which passes over a jockey pulley beyond the disintegrator spindle, see Fig. 17. The normal power transmitted by each drive is 50 h.p., but in order to provide for long life and to withstand sudden shocks each drive was designed for 200 h.p. to 250 h.p. The load is not only variable, but there is also always the possibility of foreign objects entering the disintegrator with the coal, which might injure the working parts and cause a serious breakdown as the disintegrator cages revolve at 400 r.p.m. Each driving sprocket on the line shafting (which is carried in self-oiling bearings and runs at 730 r.p.m.) is arranged with a safety shearing clutch. The sprocket is provided with a flange which aligns with a similar flange keyed to the shaft, and shear pins of suitable section connect the two together. These shear pins are of such a diameter that they shear at a predetermined overload, the driving sprocket then running free on the shaft and the machine coming automatically to a standstill. The sprocket is bushed and filled with lubricant to ensure free running when the shear pins come into action. This simple device has successfully proved its utility, for it has come into action many times since the plant started.

5. *Gravity Bucket Conveyor.*—This is of the Babcock and Wilcox standard type, as shown in Figs. 8 to 11, page 544, already referred to, and has, like the rest of the plant, a capacity of 80 tons per hour. The buckets are of mild steel each stamped out of one piece by a special hydraulic process. To the sides of each bucket a small malleable casting is securely riveted, this being a combination of a trunnion bearing and a cam, so formed that a bucket can be detached in a few seconds by the simple means of withdrawing two split pins and lifting the bucket out, not only without disturbing any other part of the chain, but also without disconnecting the latter.

Special dumpers are used for the delivery of the coal, and they are so arranged as to cause the buckets to make a series of dumps at any one point to ensure, as far as possible, complete discharge of the buckets; this is essential on account of the sticky nature of the material dealt with, as a considerable amount of moisture is added to the powdered coal prior to delivery into bunkers to ensure the coal cakes standing up under the pressure of being forced into the ovens. To ensure an even filling of the bunkers the dumpers are fixed at suitable positions over the whole area. The gravity bucket conveyor is operated by a 16-h.p. motor.

Owing to the dust created by the grinding process of the fast-running disintegrators and the confined space in which the conveyor works below them, a special device, illustrated in Figs. 18 and 19, is employed to secure quiet and dustless delivery of the small coal into the conveyor buckets without spilling.

This special feeding device (patented jointly by Messrs. Babcock and Wilcox, Limited, and Mr. Alexander Lennox) serves the double purpose of supplying fine coal in intermittent charges to the buckets of the gravity bucket conveyor, and also of isolating each charge in its own compartment from its dusty surroundings under the disintegrators, and thus feeding it to the conveyor with the minimum possible amount of dust. The feeding apparatus will be understood from Figs. 12 to 15, on page 544, these views representing, respectively, a plan and two elevations. These illustrations also show a portion of the gravity bucket conveyor in its relative position to the feeding devices, and the method in which the devices are driven from the conveyor chain by a countershaft.

The speed of these devices is naturally synchronised with that of the gravity bucket conveyor, so that each of the compartments of the former will deliver its load, without spilling, into a bucket of the latter. As may be seen from the illustrations, Fig. 18 and 19, the feeding device consists of a suitable casing in which revolves a spindle with a spider fitted with radial vanes in the form of a paddle-wheel; the vanes form pockets for the material which, when in motion, will be doled out in regular charges to the conveyor buckets. The revolving measuring device fits dust-tight into that portion of the framing between the feed hopper and the delivery outlet, so that each compartment—when leaving the feeding hopper—is perfectly isolated from its dusty surroundings. There is also a portion similarly protected where the compartments approach the opening to the feed hopper. The latter is very large, so that the material entering the compartments is not confined to the periphery of the revolving wheel, but it can likewise enter the apertures on either side of the cells. This can be seen from the photographic view, Fig. 21, on page 550. This arrangement insures that the vanes will, in carrying away the material, leave a void for further material to enter, which is quickly filled by the "flow-in" from the next compartment, which also gets a full charge. It will also be seen from the illustration that the weight of the descending load is in favour of the rotation of the wheel, the driving power expended is therefore confined to that required for overcoming frictional resistance.

In addition to feeding fine coal and other dusty materials the same device is suitable for sticky substances, or such of a sluggish nature which will not naturally flow through shoots in the ordinary way.

6. *The Overhead Bunkers.*—Mild steel coal bunkers, (see Fig. 2), are provided in two sections (an external view is given in Fig. 22, on page 550) the one directly over the coke ovens being of 300 tons capacity and arranged to feed into a travelling charging machine, to deliver powdered coal to the ovens from the top in the event of the side-charging machine not being in operation. The second section of the bunkers, delivering to the stamping and charging machine proper, is of 600 tons capacity. The outlets of the bunkers are controlled by hand-operated duplex valves; the bunkers are supported on mild steel stanchions of compound section.

The lubrication of the conveyors is an important item, and this is provided for by Messrs. Babcock and Wilcox's patent automatic lubricators. The motors employed are of the slip-ring type, manufactured by Messrs. Bruce Peebles and Co., Limited. The starting gear is of the face-plate oil-immersed type, by Messrs. Ellison, and is used for the jigger, breaker, and tray conveyor, while for operating the 200-h.p. motors driving the disintegrators, starters of the liquid type are used, these are manufactured by Messrs. Allen West and Co., Limited, of Brighton.

THE EFFECT OF THE LONGITUDINAL MOTION OF A SHIP ON ITS STATICAL TRANSVERSE STABILITY*

By Mr. G. S. BAKER, O.B.E., Member, and MISS E. M. KEARY.

§1. It has been known for many years that the distribution of forces around a ship when in motion is different from that when at rest. A little consideration makes it clear, therefore, that the stability when in motion may be different from that when at rest, and that the difference may become important as speed is increased.

The object of the experiments was to measure this effect on some typical forms, and, if possible, to determine when and why it becomes important. The actual experiments given here have been made during the past four months, but for some time all high-speed models have been specially watched for any effect of the kind. The obvious importance of the subject in connection with seaplane design led the tank staff to suggest experiments on a model of a single-float machine. These were made in the early part of 1915, and a detailed account of them is given in a report dated December, 1915, made to the Advisory Committee for Aeronautics.

The conditions which exist at the present time do not lend themselves to research work of this character. It has not been possible to test that variety of form which the authors wished, and for this reason some discontinuities are apparent. But the authors felt that this first exploration of the field had reached a stage at which the general character of the results was apparent, and that as it had taken three years to make this amount of progress, it was desirable to make the results known, rather than wait—possibly for another three years—in order to fill in the gap.

§2. *Apparatus and Mode of Experiment.*—Six models have been tested. These vary from full mercantile forms having a long parallel middle body to destroyers and skimmers. Particulars of these models are given in the table, and their midship sections in Fig. 1, page 546.

The models were made of paraffin wax in the usual way. In all cases they were at their low-water level, and on an even keel with the exception of the motor boat, which was trimmed slightly by the stern. The apparatus used for towing was, in most cases, that for ordinary ship resistance experiments† (see Fig. 2, page 546).

* Paper read before the Institution of Naval Architects, March 21, 1918.

† Owing to its high centre of gravity, the skimmer had to be propelled in another way. A vertical roller was fitted in the vertical middle line plane of the model and a horizontal one on the travelling carriage. The model was propelled by the push of the latter on the former. The propulsive force had no transverse component and therefore introduced no stability error, but its high position may have caused the model to run at slightly less stern trim than it would have done if propelled in the ordinary way.

The towing rod was attached to the model at the level of its centre of gravity, so that the pull should have no effect on its transverse inclination. Guiders were placed fore and aft at the same level; these prevented yaw, but allowed the model to trim, move fore and aft, and rise and roll quite freely. The models were ballasted to give the required trim and displacement by means of weights B in Figs. 1 and 2. These were placed along the bottom and on beams across the deck so as to bring the centre of gravity to the desired height. This was arranged in most cases to give a G.M. of 0·4 in. approximately, for the model, so that a measurable angle was obtained for a moderate inclining moment. A larger value of G.M. had to be accepted in the case of the fast motor boat. The very low buoyancy of this form for its size, was mostly taken up in weight of the wax hull. With what was left, the centre of gravity was raised as high as possible, but owing to the broad beam the metacentre was very high and the final G.M. was 5·76 in. for the model.

The required inclining moment was obtained by moving a known weight W along a slotted bar.

The angle measuring gear is shown in Fig. 1, annexed. A beam E was thrown out transversely from the model at about midships. A rod F (¼ in. by ¼ in.) was attached to the outer end of this, by a pin joint. This rod was constrained at its upper end by four rollers, J. J. The rod F carried a scale H of the transverse inclination* of the model in degrees, which was given by the long arm of a light parallel motion gear G. This gear was pivoted to the rod F at K, and balanced about this point. The beam E kept the apparatus well clear of the model and of carriage fittings, and as this was the only part attached to the model, the apparatus could be shifted easily from one to another, and no great care was required in fitting it up.

§3. *Method of Experimenting.*—The model was first trimmed so that the deck was level transversely. Following this, and at the end of each set of experiments, an inclining experiment at rest was made, the angle being taken for various transverse moments. This gave a datum curve of G.M. against angle of inclination of model when at rest. Each model was then run through a series of uniform speeds with a constant transverse inclining moment applied, and the inclination of the model whilst in motion was noted. The lower speed limit was well below the normal speed of the ship to scale, and the upper limit the highest possible for any given model. In each case an inclining experiment with the given moment was made in smooth water at the beginning and end of each run, and the mean zero of these two experiments was taken as the zero for calculation of the G.M. under way. In this manner account was taken of any shifting of weight which might have occurred during the test.

With one or two forms the experiments were repeated with another moment, and at critical speeds cross curves of varying inclination were obtained.

§4. *Analysis and Mode of Presenting Results.*—The experiments with each form gave three sets of data:—

(1) The inclinations produced when at rest, by a series of inclining moments.

(2) The inclination when under way produced by a fixed inclining moment.

(3) At critical or selected speeds, the inclination under way at constant speed with varying inclining moment.

The actual records were first converted into true inclinations of form (see footnote). The metacentric

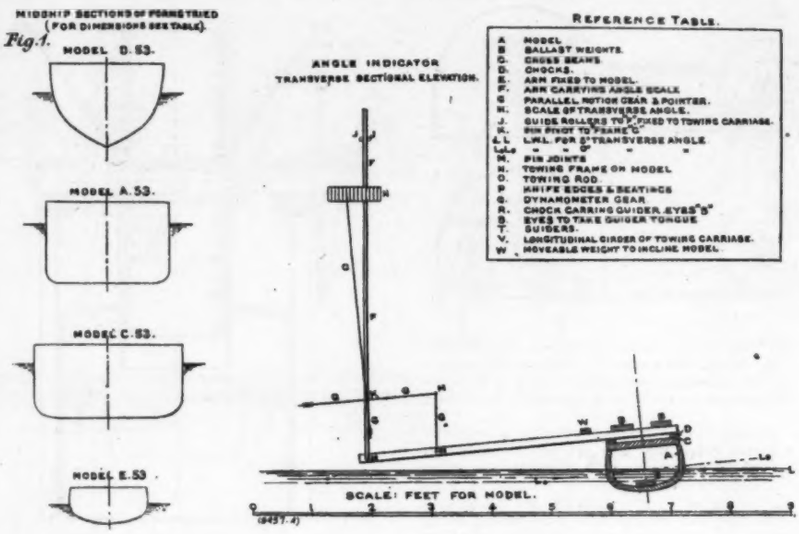

MIDSHIP SECTIONS OF FRAME TRIED (FOR DIMENSIONS SEE TABLE).
MODEL D.53.
MODEL A.53.
MODEL C.53.
MODEL E.53.
REFERENCE TABLE.
A MODEL
B BALLAST WEIGHTS.
C CROSS BEAMS.
D CHOCKS.
E ARM FIXED TO MODEL.
F ARM CARRYING ANGLE SCALE.
G PARALLEL MOTION GEAR & POINTER.
H SCALE OF TRANSVERSE ANGLES.
J GUIDE ROLLERS TO "F" FIXED TO TOWING CARRIAGE.
K PIN PIVOT TO "F" & "G"
L,L LWL. FOR 5° TRANSVERSE ANGLE
M PIN JOINTS
N TOWING FRAME ON MODEL
O TOWING ROD.
P KNIFE EDGES & SEATINGS
Q DYNAMOMETER GEAR
R CHOCK CARRING GUIDER EYES "S"
S EYES TO TAKE GUIDER TONGUE
T GUIDERS.
V LONGITUDINAL GIRDER OF TOWING CARRIAGE.
W MOVEABLE WEIGHT TO INCLINE MODEL.
ANGLE INDICATOR
TRANSVERSE SECTIONAL ELEVATION.
SCALE: FEET FOR MODEL.
(5457.4)

Fig.1.

Fig.2. MODEL TOWING AND RECORDING APPARATUS.

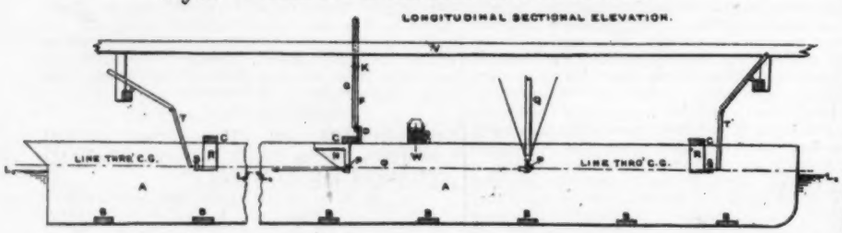


Fig.3. PLOTTING & ANALYSIS OF EXPERIMENT DATA.—MODEL D 53.

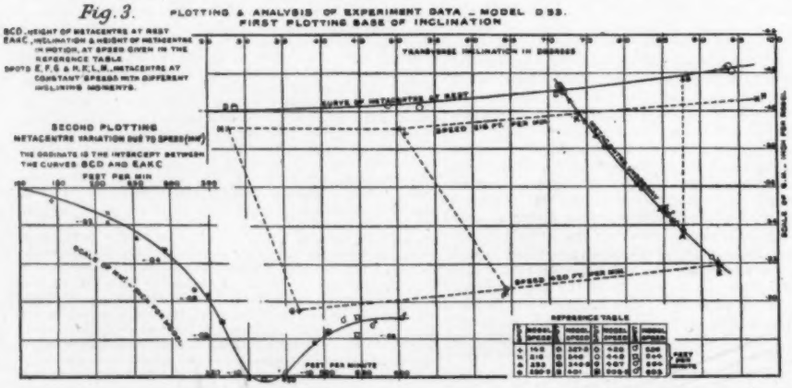
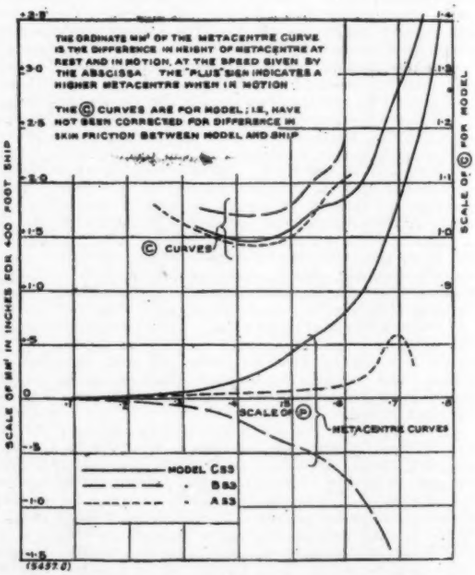


Fig.4. CURVES OF VARIATION OF HEIGHT OF METACENTRE WITH SPEED, FOR 400 FOOT SHIP


THE ORDINATE MM' OF THE METACENTRE CURVE IS THE DIFFERENCE IN HEIGHT OF METACENTRE AT REST AND IN MOTION, AT THE SPEED GIVEN BY THE ABSCISSA. THE "PLUS" SIGN INDICATES A HIGHER METACENTRE WHEN IN MOTION.
THE © CURVES ARE FOR MODEL; I.E., HAVE NOT BEEN CORRECTED FOR DIFFERENCE IN SKIN FRICTION BETWEEN MODEL AND SHIP
SCALE OF MM' IN INCHES FOR 400 FOOT SHIP
SCALE OF © FOR MODEL
© CURVES
METACENTRE CURVES
MODEL C53
B53
A53
(5457.6)

* There was a slight error in this record of varying amount on the different models, due to the transverse movement of the lower end of the rod F when the model was inclined. Corrections have been made for this in every case. When the model was inclined about 8 deg., one degree measured by the pointer was truly one degree inclination of model. The correction affected the absolute value of G.M., but hardly affected at all the differences in G.M. under way and at rest.

TABLE I.—MODEL DIMENSIONS ENLARGED TO THOSE FOR SHIP OF CONSTANT LENGTH EQUAL TO 400 FT. BETWEEN PERPENDICULARS.

Model No.	Ratio of: Ship Dimensions / Model Dimensions	Beam.	Draught.	Displacement.	Prismatic Coefficient between Perpendiculars.	Parallel Body.	Height of C.G. above L.W.L.	Metacentric Height at Rest, G.M.	Remarks.
		ft.	ft.	tons.		ft.	in.	in.	
A 53	25·5	53·0	26·0	—	0·80	110	− 75	10·0	Cruiser stern; straight line ends mainly.
B 53	25·0	54·0	27·0	13,130	0·79	185	− 64	10·3	A standard ship.
C 53	26·1	65·0	23·0	12,760	0·76	120	+ 27	9·0	Methodical series model, mercantile stern, with straight-line bow and medium hollow stern.
D 53	25·0	46·0	23·0	5,010	0·41	nil	− 23	10·0	Tank datum model having small midship section, with fine convex lines at ends.
E 53	29·0	38·0	11·0	2,540	0·64 (L.W.L.)	nil	+ 73	11·1	Destroyer of usual type with knuckle at stern and convex bow L.W.L.
F 53	30·9	80·0	12·3	3,750	0·50	nil	+431	178·0	Skimmer with chine in fore body, single step just abaft mid-section, and knuckle at after end.

height G.M. for any angle θ was then calculated from the usual formula :—

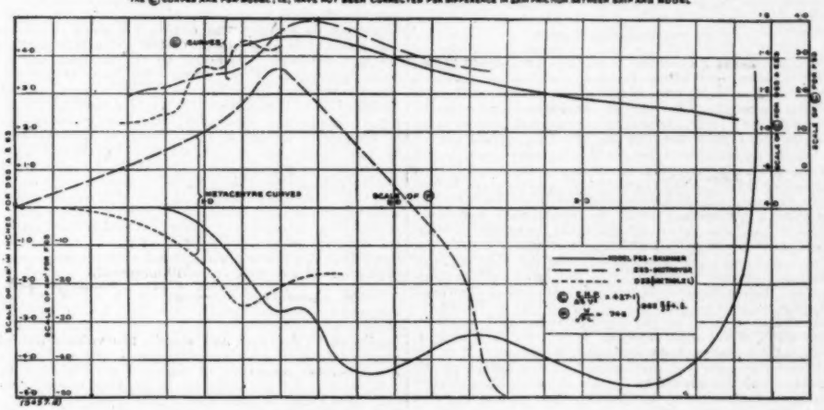
$$\text{G.M.} = \frac{\text{inclining moment}}{(\text{displacement}) \tan \theta}$$

These G.M.'s, both at rest and under way, were plotted to a base of inclination θ (see Fig. 3). The vertical intercept between any point on the "under way" curve and the "at rest" curve is a measure of the movement of the metacentre due to the water forces at the speed corresponding to the point chosen. Thus at A the speed was 487 ft. per minute, and the metacentric variation due to this speed was A B. These intercepts for the typical case chosen are given in Fig. 3, page 546.

The analysis of the results of the experiments with varying inclining moment and constant speed was only made as far as the first plotting of G.M. to base of angle, as this was sufficient to demonstrate that such variation of height of M as occurred was, roughly speaking, independent of inclination. To get a direct comparison between the forms,† his variation of G.M. was then worked out for ships of a standard length of 400 ft., and plotted to a base of (P) value.* In this way results produced by definite transverse wave phenomena are brought to more or less the same abscissa value, and can

Fig. 5.

CURVES OF VARIATION OF HEIGHT OF METACENTRE WITH SPEED, FOR 400 FOOT SHIP.
THE ORDINATE R.M' OF THE METACENTRE CURVE IS THE DIFFERENCE IN HEIGHT OF METACENTRE AT REST AND IN MOTION AT THE SPEED GIVEN BY THE ABSCISSA. THE "PLUS" SIGN INDICATES A HIGHER METACENTRE WHEN IN MOTION.
THE (C) CURVES ARE FOR MODEL; I.E., HAVE NOT BEEN CORRECTED FOR DIFFERENCE IN SKIN FRICTION BETWEEN SHIP AND MODEL



be easily detected. These curves for all the models are shown in Figs. 4 and 5. On each diagram is also shown the (C) value† of the model to the same abscissa. Serious wave-making is indicated by a rapid upward trend of the curve of (C), and this is usually accompanied by a change in the character of the G.M. curve.

Before passing to the results obtained it is desirable to consider in what different ways the transverse stability may be affected by longitudinal motion. The effect may arise from a number of separate causes, all of which exist in any case, but whose relative importance varies greatly with form, speed, &c. These causes may be roughly classified as :—

1. Stream-line pressure changes considered as distinct from
2. Wave or surface motion,
(3) Alteration of water line due to trim or sinkage,
4. Inclined plane or jet action.

§5. *Stream-line Pressure Changes.*—The statical transverse stability of a ship is obtained in one of two ways, either by keeping the centre of buoyancy high, or by working with a large water-plane area to give good water moment from small inclinations, *i.e.*, a large inertia of water plane and "B.M."

The height of the centre of buoyancy is always taken to be the centre of gravity of the displaced water, the ship being at rest. But this is not necessarily the case when in motion. Adopting for the present the conventional supposition of a rigid water surface, calculation shows that the pressures around any form when in motion differ from those when at rest, there being regions of aggregate increased pressure at each end and diminished pressure between them. The total effect of the latter is usually greater than that of the former, and to maintain its buoyancy the form must be immersed a small additional amount (see §6).

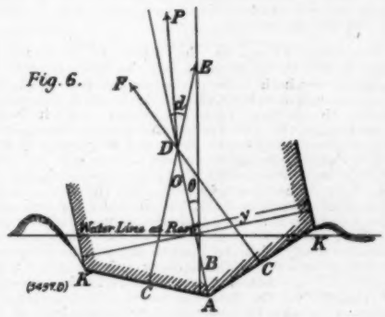
§6. *Surface and Running Trim Effect.*—If the conventional rigid surface is replaced by one of constant pressure, as is the case with all surface ships, the surface particles adjust themselves to the new conditions by change in water-level and in stream-line motion. This adjustment involves some very rapid rotary movements of the streams which go to form the bow breaker or first divergent wave, and the ordinary accepted orbital motion in the transverse waves formed. Wherever rotary motion* takes place, there is a corresponding change in the virtual gravity, and consequently in the real buoyancy of the water.

The centre of action of the buoyancy obtained under these conditions will depend upon the vertical distribution of these hydrodynamic pressures at each section of the ship. If this were known, the new centre of buoyancy could be calculated by a little extension of the system used by Sir William Smith in his paper on "Hogging and Sagging Strains in a Seaway influenced by Wave Structure,"† which gives a method of calculating buoyancy with any pressure distribution. The pressures, however, are not known and are difficult to measure, but it can be seen that either a concentration of pressure near the water line where the sections flare, or a reduction of pressure all over the midship portion of a ship, would raise the centre of "buoyancy" a little.

There is a second effect produced by running trim, viz., variation of inertia of water plane. In most mercantile vessels this is slightly greater under way than when at rest. In destroyers the water line varies with speed, but is not materially different from the at-rest condition except at the bow, where the marked motion of the water at high speeds makes it impossible to give any value to water-line effect in that region.

§7. *Inclined Plane of Jet Action.*—This may affect

Fig. 6.



all vessels to a small extent, but is important only in the case of high-speed ones, and detailed consideration has been confined to these alone.

A skimmer running at high speeds is wholly supported by the dynamic forces due to the water impinging on its bottom. When at rest it is supported entirely by the hydrostatic lift or buoyancy of the water it displaces. As the vessel attains speed there must come a time when the line of action of the supporting forces, and therefore the stability, must be due more to the dynamic than to the static forces. As these are unrelated to each other, some variation of stability with speed must be expected.

In the case of an ordinary ship form at low speeds the restoring couple at angle θ is given by :—

$$\left[w \Sigma \frac{2}{3} y^3 \, dx - \text{W B G} \right]$$

B being the centre of buoyancy,
G being the centre of gravity,
y the half-beam at any point x of the length in feet,
W being the displacement,
w the weight of 1 cub. ft. of water.

When planing is fully developed, if the bottom is regarded as two inclined planes A, K, in Fig. 6, forces E and F will act on the two sides. Their relative value will vary with transverse inclination, partly because of the transference of effective area from the emerged to the immersed side, and partly because of the effect of transverse inclination on the lifting value and on the longitudinal angle of attack of the two sides (both will be greater on the immersed side under the condition assumed).

An elementary idea of the changes taking place can be obtained from the following simple case. It is assumed that the planing surface has a V-section and that the forces on the two sides will act at right angles to the bottom, and at the same points C and C_1 for all small transverse inclinations. If when inclined at an angle θ a lift p is transferred from one side to the other, a couple is introduced equal to :

$$2 p \, \text{G D} \sin a,$$

where D is the intersection of the lines of action of the forces on the two sides, and a is the inclination of these forces to the middle line. This is a restoring couple when D is above G. The restoring moment now becomes :

$$\text{M} = \left[\Sigma w \frac{2}{3} y^3 \, dx - (\text{W} - \text{P}) \, \text{B G} \right] \theta + 2 p \, \text{G D} \sin a$$

P being the resultant dynamic lift on the bottom,
B the centre of buoyancy of the immersed volume

$$\left(\frac{\text{W} - \text{P}}{w} \right).$$

When the vessel is properly planing, the water-plane area is very small and the transference of buoyancy nil, so that the integral is negligible, and P is then equal to W. The whole restoring moment then depends upon the last term in the above equation. This will obviously depend upon the beam, and the rate of transference of force from one side to the other with inclination, and experiment only can determine its value.

Up to this point the inclined plane action has been assumed to be independent of the surface disturbance and to continue at all inclinations, but observation in a number of cases has shown that this is not the case. The continuance of good planing action on the immersed side, when inclined, depends upon a proper feed of air to the step, and the ability to keep the chine line from becoming immersed. If either of these things is wanting, to the same extent is there a falling-off in lift on this side. Either immersion or larger wave formation may produce this effect, and no great result can be expected from the inclined surface until the step has properly cleared itself.

§8. *Results.*—These have been analysed only so far as to give precise data for the individual forms concerned. When more models have been tested and circumstances allow of more time being devoted to the subject, the analysis will be carried farther, so that results may be predicted for any given form. From what has been done, however, certain general conclusions are evident, viz. :—

1. For all vessels there is a systematic variation of stability with speed.
2. This variation is never important unless the wave-making resistance is important.
3. In ordinary tramp steamers and low-speed mercantile vessels a small loss of metacentric height, not exceeding 5 in., may be obtained.
4. With higher speeds—within range of many existing vessels (besides destroyers)—variations in metacentric height of from + 3 in. to − 2·3 in. have been obtained with quite normal forms of different type, and these must be regarded as quite possible variations for forms capable of running at speeds between (P) = 1·0 and 1·5,
5. At still higher speeds (*i.e.*, above (P) = 1·5) and before a vessel begins to plane or skim, it suffers from considerable loss of stability due mainly to the bad action of the step and the after end being partially under water on the immersed side.
6. Destroyers which work in the speed range covered by (5) suffer from this same loss of stability.
7. When a vessel* is planing with the chines and step running quite clean, it can derive a large amount of stability from the action of its planing surfaces.
8. In all the models tried the variation of metacentric is, roughly speaking, independent of the transverse inclination of the form within the experimental limits of inclination, viz., 7 deg. to 9 deg. maximum at rest.
9. The movement of the metacentre is not proportional to the square of the speed.

Of these conclusions, No. 4 has the greatest practical importance, but Nos. 2 and 8 have a greater bearing on the study of the phenomena. These show that the effect is set up by the longitudinal motion alone, that it is not brought on by the transverse inclination, but exists when the ship is at any angle, including the upright position.

Some minor points of detail to which attention can usefully be drawn are as follow :—

(a) Models D and E differ in the former being twice as deep as the latter and having an after body the same as its fore body instead of the usual cut-up stern of a destroyer as in E. The wave formation at the bow of the two forms was of the same character. At the after end D had a large wave crest similar to that at its bow, but this wave crest never formed against the hull of E, which rode with its knuckle line at or about the water-level wherever this might be. The movement of the metacentre in these two forms at corresponding speeds was in opposite directions, and this difference

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$$* \text{(P)} = 0.746 \times \frac{\text{V}}{\sqrt{\text{P L}}},$$

where V is the speed in knots, P is the prismatic coefficient, L is the length in feet.

$$† \text{(C)} = 427.1 \times \frac{\text{E.H.P.}}{\Delta^{2/3} \text{V}^3}$$

where Δ is tons displacement.

* With rotary motion the virtual gravity is given by $(g - \omega^2 r)$, where ω is angular velocity and r the radius of movement. Assuming trochoidal waves, this reduces to $g\left(1 \mp \frac{r}{\text{R}}\right)$, where r and R are orbital and rolling circle radii respectively.

† Transactions of the Institution of Naval Architects, 1883.

* Although the results for only one model are given to support this conclusion, accurate experiments with three others and general observation of another go to show that it is correct.

in behaviour must be attributed to a large extent to the different stream line and wave motion at the after end.

(b) A chine in the fore body has a large effect upon the variation of metacentre, and the character and position of the chine are more important than the general shape of the form above and below it (assuming the shape to follow conventional lines). It either controls, or failing that, damages the stream-line and wave formation.

(c) Conclusion 9 is not altogether unexpected. If a fully-submerged body moves through the water, theoretically all the forces vary with the square of the speed. But the draught of a body moving on the surface is continually changing, and, what is more important, the disposition of the hydrodynamic pressures in the surrounding fluid is also changing with speed, and this change is mainly governed by the possible wave formation. It is the disposition of the water pressure more than their aggregate value at any section of the ship that determines their effect on the stability.

These conclusions have been confined strictly to the matter in hand, and their indirect bearing on the rolling and straining of ships at sea has not been discussed, although it may in some cases be appreciable.

The authors' thanks are due to Mr. A. W. Riddle, who has performed a good deal of the office work in connection with the research.

THE PHYSICAL SOCIETY OF LONDON.

At the meeting held on April 26, at the Imperial College of Science, Professor C. H. Lees, F.R.S., president, in the chair, a paper, entitled "*Notes on the Pulfrich Refractometer*," was read by Mr. J. Guild. The paper deals with points to be observed in the use and design of Pulfrich refractometers. A theoretical investigation of the various errors to which measurements are liable is included.

A paper "*On the Accuracy Attainable with Critical Angle Refractometers*" was read by Mr. F. Simeon. The three factors controlling the determination of a refractive index by means of a critical angle refractometer are, so far as the prism system is concerned (i) the angle of the prism, (ii) its refractive index, and (iii) the angle of emergence of the critical ray from the second prism face. Expressions are obtained for the variation of the required refractive index with each of these factors separately and curves are given connecting these variations with the angle of emergence from the second prism face for various prism angles.

Mr. Simeon expressed interest in certain of the points mentioned in the first paper. He described the new graticule fitted by Messrs. Hilger. He was surprised that no reference to temperature measurements was made in the paper.

Mr. T. Smith pointed out that the work which formed the basis of the first paper involved the measurement of some 2,000 glasses, and was only possible where combined facilities for routine and research work were available on a large scale. He thought Mr. Simeon's curves should have been plotted against refractive indices instead of emergent angles. At present they were misleading. The mathematics could also be simplified.

Mr. Lamplough said he could confirm the advantage of using different liquids with different glasses. He thought Hilger's new graticule very comfortable to use. What was Messrs. Hilger's object in reversing the parts of the instrument?

Mr. Churcher referred to the design of the Abbé refractometer and pointed out the necessity for having the lower illuminating prism of dense glass as well as the upper prism.

Mr. Guild replied to the points raised by the various speakers on his own paper, and expressed his interest in the statements made by Mr. Simeon about some of the features of Messrs. Hilger's new instrument. He criticised Mr. Simeon's paper on the ground that he was not comparing properly comparable quantities in the case of the different prisms, and that his conclusions and also those that would be drawn from his curves were unduly favourable to the 90 deg. prism on this account.

Mr. Simeon said he had not himself found it misleading to use curves plotted to angles of emergence and that he had found the curves most useful in many cases. The object in reversing the parts of the instrument in their new model was to bring all the adjustments within reach of the observer's right hand.

Professor Lees emphasised the importance of close co-operation between the users and manufacturers in order to evolve the most satisfactory instruments for work of high accuracy.

Mr. L. C. Martin (communicated remarks) thought the setting of the Pulfrich refractometer must be more sensitive to errors from causes such as radiation, &c., than the symmetrical setting of the ordinary spectrometer.

Mr. W. French (communicated remarks on Mr. Simeon's paper) thought it would be useful if the author extended the paper to cover the factors that determine the accuracy in the actual use of the instrument in addition to those governing the first design.

A paper, entitled "*Cohesion*" (fourth paper), by Professor Herbert Chatley, was taken as read. The paper is the fourth of a series dealing with the subject of Cohesion. The aim of the present paper is to consider the value of molecular force as indicated by Van der Waals gas formula (particularly at the critical state where the liquid and gaseous states merge), and to relate the results to the previous inquiry.

Dr. H. S. Allen (communicated): In this paper, Professor Chatley has pointed out a number of interesting relations depending on the equation of Van der Waals. It is more than doubtful whether any attempt to found a theory on purely central attractions and repulsions varying as some power of the distance can prove adequate to explain the facts. It is certain that the law of attraction at molecular distances is not that of the inverse square of the distance. In a lengthy series of papers in the *Philosophical Magazine*, Sutherland*, whose work has not received adequate recognition, has discussed the law of the inverse fourth power, and has pointed out the relation which it bears to the characteristic equations of Van der Waals and others. A useful summary of work on the subject is given by W. C. McC. Lewis, in his "System of Physical Chemistry" (Longmans, 1916). It may be mentioned that Lewis† has examined the connection between the internal pressure or cohesion, π, in the equation

$$(p + \pi)(v - b) = RT,$$

and the dielectric capacity and permeability of a liquid. He has shown that the Obach Walden relation regarding the proportionality between the internal pressure and the dielectric constant follows from the hypothesis that molecular attraction is electromagnetic, not electrostatic in nature. That cohesion arises from the action of electric or electro-magnetic forces may be inferred from optical experiments. The Lorentz-Fitzgerald hypothesis explains the negative result of the Michelson-Morley experiment by a contraction of the material framework of the apparatus in the direction of its motion through the æther. Such a contraction may be predicted from the standpoint of electromagnetic theory. There is, therefore, a strong presumption that "the forces of cohesion between the particles which give a solid its rigidity are electrical forces."‡

EXPERIMENTAL CONSTRUCTION OF AERO-ENGINES.—The Minister of Munitions has ordered as follows: (1) On and after May 15, 1918, no person shall without a licence from the Minister of Munitions commence or proceed with the experimental construction of any aero-engine; provided that where a first application for a licence under this Order shall have been made and is pending for the carrying on of any experimental construction which shall have been commenced before May 15, nothing in the Order shall prohibit the carrying on of such construction until the licence shall have been refused. (2) The term experimental construction shall mean any construction which is not under or for the direct purpose of fulfilling a Government contract, and shall include the preparation of any working drawings but not the preparation of general arrangement drawings. (3) Every person desirous of obtaining a licence to commence or carry on any such experimental construction as aforesaid shall apply in writing to the Director-General of Aircraft Production, Kingsway, W.C. 2, for such licence, and shall give full particulars of the construction for which the licence is required, and such further information as the Director-General may require, and shall comply with any restrictions or conditions subject to which the grant of such licence may be made.

CONCRETE SHIPS.—In the House of Commons, on May 8, Mr. P. A. Harris asked the First Lord of the Admiralty whether Italian concrete ships had been built and had been in regular service in the Mediterranean and in the Adriatic some ten years; and whether he would state the tonnage of the largest British-built, concrete sea-going vessel afloat, and how many British-built, concrete sea-going vessels of over 400 tons gross register were afloat. Mr. Pretyman replied that it was the fact, so he was informed, that the first concrete vessels were built in Italy, but they were of very small dimensions and of no commercial value. In fact, some of them were small rowing boats. The largest concrete vessel actually afloat in English waters was a barge of a little over 400 tons, and this was the only one which had so far been launched. Answering further questions he stated that the first reinforced concrete ship constructed in the United States was launched at San Francisco some six weeks ago. This vessel had a dead-weight carrying capacity of 5,000 tons, but beyond this vessel no other of the same material had been launched. No vessel built of reinforced concrete had so far reached this country from the United States, and it was unlikely that the vessel which he had already referred to would be sent to the United Kingdom. Should it be found possible to send such a vessel across the Atlantic, every advantage would be taken of such a voyage in order to submit the vessel to a practical test and to obtain such information as would enable construction of vessels of similar types to proceed as rapidly as possible. Full particulars of the vessel had been received in this country, and full advantage was being taken of this information. Every encouragement was being given by the Admiralty to this new industry, several newly-formed yards having been laid down specially for constructing concrete craft, while existing shipyards had been encouraged to form branch establishments for the same purpose without interference with the building of steel vessels. Whilst it was true that at present no vessels of more than 1,000 tons were being constructed to the order of the Admiralty, it should not be forgotten that there was a very urgent demand for vessels of small tonnage which could be rapidly constructed. In view of this it was decided to concentrate on the smaller craft until more experience had been obtained as to the construction of such craft and, what was of much more importance, as to their behaviour when at sea.

* Sutherland, *Phil. Mag.*, vol. xxiv. page 113, page 168, 1887; vol. xxxv. page 211, 1893.

† Lewis, *Phil. Mag.*, vol. xxviii, page 104, 1914.

‡ Eddington, *Nature*, vol. ci, page 15, 1918.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Trade.—During the month of April, 201,055 tons of coal were imported to Hull, as against 203,031 tons in the corresponding month last year, a decrease of 1,976 tons. The receipts for the four months ended March 31 last amounted to 859,621 tons, compared with 931,746 tons in the same period twelve months ago, a decline of 72,125 tons. Denaby and Cadeby Main heads the April imports list with 21,092 tons, making the total amount for that colliery this year 95,133 tons.

Works Extensions.—Notwithstanding the fact that the ranks of labour continue to be freely drawn upon for Army recruits, and that similar projects in the city are being retarded by the scarcity of men, Sheffield firms continue to submit plans of works extensions to the corporation for approval.

Whitsuntide Holidays.—Except in cases where work of great importance is being done, the usual holiday will be observed at Whitsuntide. That means that probably a greater portion of the local army of labour will enjoy the first respite since Christmas, the Easter holiday being at the last minute withdrawn in most firms, in consequence of the sudden development of the German offensive.

Iron and Steel.—While conditions remain exceedingly brisk in most departments specially concerned with material for the prosecution of the war, there is a pronounced slackness in purely commercial trade. The output of steel for tanks, aircraft and shipbuilding continues to employ the entire resources of makers. The home calls for high-speed steel are active, but they are not anything like equal to the amount which is being produced. Freer export facilities would bring about a welcome improvement in this respect, and such facilities would undoubtedly prove acceptable from a purely commercial standpoint. But the authorities show no inclination to remove the embargo on overseas trade. So binding are the restrictions, that they interfere with urgent orders which are sanctioned for Allied countries. Delivery of these orders is being continually delayed by the tardy appearance of the official permission, without which they cannot be shipped. Dissatisfaction continues to be caused by the way in which raw materials are coming to hand. The cause of the trouble is not so much that there is not a supply as that the facilities for transporting it to makers are ill-managed.

South Yorkshire Coal.—Supplies in all departments are markedly inadequate. Output, which has been considerably affected by army recruiting among miners, continues to decrease, and should the volume diminish much further, as there are signs that it will undoubtedly diminish, the question of supplies will become very serious indeed. This applies to all consumers of fuel, and there is the greatest need for every possible economy being practised. Best steams are in great demand both for home consumption and export. Cobbles, nuts and slacks are all firmly held, and household sorts are actively sought. Cokes of all sorts are scarce, and prices generally are at the maxima. Most of the orders despatched from collieries, with as much expedition as the transport facilities will permit, are on contract account, there being practically no "free" fuel offering. Quotations:—Best branch handpicked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.* 6*d.*; best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; small nuts, 17*s.* 6*d.* to 18*s.* 6*d.*; Yorkshire hards, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire hards, 17*s.* 9*d.* to 18*s.* 9*d.*; best slacks, 14*s.* to 14*s.* 6*d.*; seconds, 13*s.* to 13*s.* 6*d.*; smalls, 9*s.* to 10*s.*, per ton at the pit.

ENGINEERS' AND MACHINISTS' SMALL TOOLS.—The Minister of Munitions has ordered as follows: No person shall, on or after the first day of June, 1918, until further notice, manufacture any small tool as stated in a list attached to the Order, or any part of such tool, except under and in accordance with the terms of a licence issued under the authority of the Minister of Munitions. Every person engaged in the manufacture of small tools shall make such returns with regard to his business as shall from time to time be required by or under the authority of the Minister of Munitions. All applications for licences under this Order shall be addressed to the Controller of Machine Tools, Charing Cross Buildings, London, W.C. 2, and marked "Small Tools."

PURCHASE BY GOVERNMENT OF AUSTRALIAN ZINC CONCENTRATES.—An agreement has recently been made between the President of the Board of Trade, representing His Majesty's Government, and the Zinc Producers' Association Proprietary, Limited, of Australia, for the purchase by Government of the stocks of Australian zinc concentrates existing at December 31, 1917, less reserves, and, subject to the reasonable protection of Australian requirements, the production from January 1, 1918, to the maximum extent of 250,000 tons per annum for the period of the war and one year thereafter, and 300,000 tons per annum for the subsequent nine years. His Majesty's Government also secures an option over the balance of production subject to certain reservations, such as provision for the requirements of Australian zinc-refining works and the fulfilment of existing contracts. The agreement, which varies an earlier agreement by enlarging the quantity and modifying the purchase terms, provides for a "flat rate" of prices up to the end of five years after the war. For the remainder of the period prices will be determined by market conditions with the "flat rate" of the earlier period as a minimum.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—While the demands for steel, both finished and semifinished, show no signs of diminution, evidence is not wanting to show that now, even with the various drawbacks which manufacturers have to encounter, these demands are being met in a particularly satisfactory manner. This does not mean that any slacking off in production is at all probable, quite the contrary, for every rolling mill is employed to its fullest capacity, and the output in the whole district as well maintained as labour conditions will permit. The shortage of workers is still a serious problem not easy of solution, and, in addition, supplies of raw material are not always forthcoming in sufficient quantity. Despite these barriers, however, ship and boiler plates and sections are being delivered to the shipyards in an ever-increasing tonnage, and all kinds of constructional material for the locomotive works, munition factories and general engineering shops. Some shipments of a strictly limited nature are being despatched to the French Government for war purposes, but beyond this and a small tonnage to the Indian Government, no export is being attempted.

Malleable Iron Trade.—Everything produced by the malleable iron makers, alike of their iron and their steel departments, is promptly absorbed on war account, and the bar mills are running incessantly day and night. Naturally, the output is most extensive, yet so great is the demand of the home consumers that nothing remains on the market, or is available for export—work of national importance has first claim.

Scotch Pig-Iron Trade.—Production of pig-iron is limited alone by the quantity of ore obtainable and the labour at the command of the smelters. Were it possible to have these two sources of supply augmented there could be no question regarding an increased output. All the same, this has now reached a very high level, although the requirements of the iron and steel works continue to be in excess of even this extensive production. The necessities of consumers are urgent in the extreme, and with the Government rationing scheme now in vogue each is dealt with and supplied according to the urgency of the case. Government contracts having first claim, the general mercantile trade has to stand aside, and so also has export. Although home prices are still fixed, some little latitude has crept in.

Wages Claim by Clyde Shipwrights.—An interesting point has just been settled by Sheriff Fyfe in regard to a claim made by the Shipwrights' Trade Society, at the Glasgow Munitions Tribunal. About two and a half years ago objection was taken by the shipwrights to the system of payment by results and, to meet their demands, the employers took the whole question into consideration, evolving a scheme, practically one of premium bonus, which was accepted by the men. This worked quite satisfactorily until February of this year, when the men demanded the 12½ per cent. bonus granted to time workers in October, 1917. The 12½ per cent. advance was then acceded to them and the other allowance dropped, and the Sheriff has now decreed that the men are not entitled to both.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—With the supply of trucks still steadily improving, and Cleveland pig-iron quite plentiful, distribution of iron to home consumers is expanding, and this month's deliveries promise to be heavy. Contracts for foundry quality under the original allocations for May have all been made, but supplementary allotments are looked for. A rather extensive business in forge iron is passing both for early and forward delivery. This description does not come under the allocation system. Forge thus finds a ready market, and is being delivered freely. Foreign trade is confined to transactions with France and Italy, but whilst shipments to the former are well maintained, exports to Italy are on a very limited scale. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge all stand at 95*s.*, and No. 1 is 99*s.*; and for shipment to the Allies, No. 3 and the lower qualities are quoted 114*s.*, and No. 1 119*s.*

Hematite Iron.—The tonnage situation does not admit of much hematite iron being shipped, but home consumers are receiving adequate supplies, without, however, leaving them with opportunity for accumulating stock. Use of basic iron and scrap, in the manufacture of steel, is now heavy, and is still increasing, so that the hematite position promises further to improve. Mixed Nos. of East Coast hematite are 122*s.* 6*d.* for home use, and 147*s.* 6*d.* for export to France and Italy.

Manufactured Iron and Steel.—As regards the manufactured iron and steel trade there is no relaxation of pressure. Output of material for the shipyards continues on a huge scale, but it is gratifying to learn that in this department needs have been overtaken, so that producers are in a better position to cope with the heavy accumulation of other orders. Government requirements, however, still absorb the attention of manufacturers, and opportunity of transacting ordinary commercial business is no better. Prices, all round, are very stiff. To home customers the following are among the principal market quotations:—Common iron bars, 13*l.* 17*s.* 6*d.*; best bars, 14*l.* 5*s.*; best best bars, 14*l.* 12*s.* 6*d.*; iron ship plates 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; steel strip, 17*l.* 10*s.*; steel hoops, 18*l.*; heavy sections of steel rails, 10*l.* 17*s.* 6*d.* Export prices are not fixed, but they run approximately from 40*s.* to 60*s.* above home rates.

Coke.—Up to the present the large demand for coke has been satisfactorily met, but signs are not wanting of difficulty in maintaining adequate supplies in the immediate future. Quotations are strong. Average blast-furnace coke is 33*s.* at the ovens, low phosphorus sort 35*s.* 6*d.* at the ovens, and foundry kind 38*s.* for home use; whilst for shipment to neutrals nothing below 50*s.* is asked for both furnace and foundry coke.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—On the coal market this week the matter of chief concern has been the shortage in the supply of coal. There is now less labour employed in the coalfield than at any time since the outbreak of war, but as against this diminution in the supply of labour there has been a more than compensating increase in the demand for coal, and if the miners were working up to their opportunities the quantity of coal produced just now ought to be over, say, monthly periods, quite as great as, if not greater than, it was when employment was irregular. The complaints of salesmen is that there is much needless absenteeism. How much of this is deliberate it is impossible to say; but there is no excuse for the younger men to abstain from work when their fellow workmen are being called up for examination for military service, and from this cause alone there is an appreciable loss of production. The suggestion can hardly be credited that in such an emergency as the present there is calculated ca' cannyism in the coalfield; but the position on the labour side is generally very unsatisfactory and the hope is expressed that there will be no loss of time in putting into force measures which will secure the maximum output possible so long as the demand remains favourable. All classes of coal are scarce, and very little is being shipped to neutral destinations, and no instance has yet been reported of the payment of prices above the scheduled figures for such destinations.

Newport.—The shortage in the supply of coal continues, and it is regrettable that through avoidable causes production in the Eastern and Western Valleys of Monmouthshire is being restricted. The Tredegar Collieries are still idle and the workmen at the Prince of Wales' Pit of the Ebbw Vale Company were idle on Monday and Tuesday as a protest against altered train service. The demand for inland consumption is strong, and there is evidence that householders are taking more than is customary at this period of the year.

Further Suspension of Coal Allocation Scheme.—At a meeting of the South Wales Coal and Coke Supplies Committee yesterday it was decided that under the allocation scheme all colliery companies in the coalfield are to be permitted to work the fullest possible output in the four weeks May 11 to June 8 inclusive. This means really the suspension of the scheme for the allocation of orders for the period indicated.

Distribution of Coal to South-Western Counties.—The scheme prepared by the South Wales Coal and Coke Supplies Committee for the distribution of Monmouthshire and South Wales coal by water and by rail to the South-Western Counties (Area No. 13) has now received the sanction of the Coal Controller, at whose request it was prepared. For some time past traffic between South Wales and the South-Western Counties has been in a state of congestion and the purpose of the new scheme is to relieve the overburdened condition of the railways by a more systematic despatch of coal by rail and the shipment of a larger quantity by trows. The main feature of the scheme is the division of the South-Western Counties (known as Area 13 under the transport reorganization scheme) into six zones with a central office at Cardiff to deal with all orders in conjunction with the Cardiff Coal and Coke Supplies Committee. In each of these zones there has been appointed a representative who is a coal factor. All orders for deliveries will be sent by the consumer to the factor, merchant or colliery company from whom supplies were previously ordered, such factor, merchant or colliery company will then send the order to the representative for the zone in which the station is situate at which the coal is required, and he, in his turn, will transmit it to the central office at Cardiff. The coals to be sent by trow will be mainly steam and manufacturing descriptions, while in regard to the despatch of house coal an important change, and one calculated to effect considerable economy in transport, is that by which, orders will be executed in train loads from individual collieries and not in relatively small isolated quantities as has hitherto been the case. Railway locomotive coal by rail, coals sent to Government factories by rail, and Admiralty coal, are excluded from the scheme. One uniform price of 25*s.* per ton at pit is to be paid for all South Wales and Monmouthshire coal for household purposes after June 1, whether sent by rail or water or whether supplied under contract or otherwise. The controlling authority will be the Coal and Coke Supplies Committee acting under the direction of the Coal Controller.

PERSONAL.—The Tudor Accumulator Company, Limited, of 3, Central Buildings, Matthew Parker-street, Westminster, S.W. 1, have disposed of the business in rail welding hitherto carried on by them, to their managing director, Mr. Edwin Jacob, who will continue the business on his own account as "The Rail Welding Company."

NOTICES OF MEETINGS.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, May 23, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. (Light refreshments at 5.30 p.m.) "Some Transient Phenomena in Electrical Supply Systems," by Professor E. W. Marchant, Member.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 24, at 5.30 p.m., a discourse will be delivered by Lieutenant-Colonel A. G. Hadcock, R.A., F.R.S. The subject will be "Internal Ballistics." Afternoon Lectures at 3 p.m.:—Tuesday, May 21: Professor Arthur Keith, M.D., F.R.S., Fullerian Professor of Physiology, Royal Institution, on "A Master of Method—Pitt-Rivers" (Lecture V). Thursday, May 23, Lieutenant-Colonel Sir Francis Younghusband, K.C.S.I. K.C.I.E., on "The Abode of Snow: Its Appearance, Inhabitants, and History" (Lecture I). Saturday, May 25: Professor Charles J. Patten, M.D., Sc.D., on "Problems in Bird Migration" (Lecture I).

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 24, at 7.30 p.m., at the Offices of the Institution, 39, Victoria-street, Westminster, S.W., an Extraordinary Resolution dealing with increase of subscriptions will be submitted.

THE ALUMINIUM INDUSTRY.—It was stated at the general meeting of the Aluminium Industry, Limited, Neuhausen, that the increase of the company's capital, from 35,000,000 francs to 42,000,000 francs, from the gross profits, was only following the example of other aluminium works. Thus a French aluminium company had increased its capital during the war from 16,000,000 francs to 40,000,000 francs, and finally to 80,000,000 francs. With regard to the auxiliary companies of the Aluminium Industry, Limited, it was announced that, apart from unforeseen events, the aluminate deliveries from the Goldschmeden chemical works and the Martin works should, during the current year, cover the entire requirements of the company.

TEMPERATURE CONTROL OF SUPERHEATED STEAM.—The temperature of the steam from a superheater depends upon so many variables that means for temperature control have to be added to any design of a superheater plant. The dryness of the steam leaving the boiler changes with the circulation and thus with the load. There is no reliable simple formula for the heat transmission from the flue gases to the steam, and the conditions of stoking influence the temperature and velocity of the gases and the steam to uncertain extents. Reviewing this problem in a recent article (*Zeitschrift Verein Deutscher Ingenieure*, pages 883 to 888 and 921 to 924, November 3 and 17, 1917), H. Huebner, of Cologne, distinguishes three types of temperature control, by the aid of dampers, by water cooling, and by varying the moisture content of the saturated steam. The damper control appears the most correct in principle, as it protects the coil to be guarded against excessive superheating (whilst the other methods rather try to correct mischief done), and is most largely in use. The usual swinging damper doors of cast-iron are heavy, however, and strain the settings; sliding doors of refractory materials have hence come into favour, or by-pass flues are provided through which part of the gases escape without entering the superheater; but the by-passes complicate the setting and must lower the boiler efficiency, even when the deflected gases are sent through an economiser. Attention has hence been directed to the second method, cooling of the superheated steam by the boiler water. In the Babcock and Wilcox device, one of the most efficient of this type, radiator pipes are placed in the boiler water, and they are joined to the superheater by a three-way valve, by means of which all or part of the superheater steam may be sent through the cooling pipes and back into the system. In the Klose system the cooling or heat-exchanging pipes are so suspended by flexible tubes that they are automatically submerged in the boiler water when the superheat exceeds a certain limit; the device comprises a thermostat with electric contacts and an electric motor. In the simpler device of the Sächsische Maschinenfabrik, late A. Hartmann, the cooling pipes lie in a drum which is charged with the warm feed water and from which the steam raised goes to the main boiler. Wedertz places the cooling tubes, through which boiler water flows, concentrically in the pipes of the end section of the superheater, which is thus protected against overheating. The third method purposely primes the saturated steam before it enters the superheater. Steinmüller attains this by the aid of a by-pass and a Dubiau pump, beneath the bell of which a small portion of steam is caught; this steam and some water pass through a bundle of pipes into a shallow dish, from which a spray descends, which is carried up by the main steam from the front header. The Germaniawerft, again, makes use of cooler tubes which are concentrically mounted within the superheater pipes and held in position there by a strip of sheet metal helically wound round the cooler tube; this tube serves as injector, however, and is provided with fine perforations (also in a helical line) through which water is forced when the superheating becomes excessive and a valve is opened. Huebner also mentions the regulator of Walther and Co. which is to prevent any but distilled water from reaching the superheater, so that no scale can be deposited in the superheater. The regulator is a small surface condenser, through the pipes of which feed water circulates, whilst steam from the boiler passes over the pipes on its way to the steam-feeder for the superheater; the saturation of this steam can be varied.

COAL-HANDLING PLANT AT THE SALTLEY GAS WORKS, BIRMINGHAM.

CONSTRUCTED BY MESSRS. BABCOCK AND WILCOX, LIMITED, ENGINEERS, LONDON.

(*For Description, see Page* 541.)

Fig. 20. Disintegrators.

Fig. 21. Coal-Feeding Device.

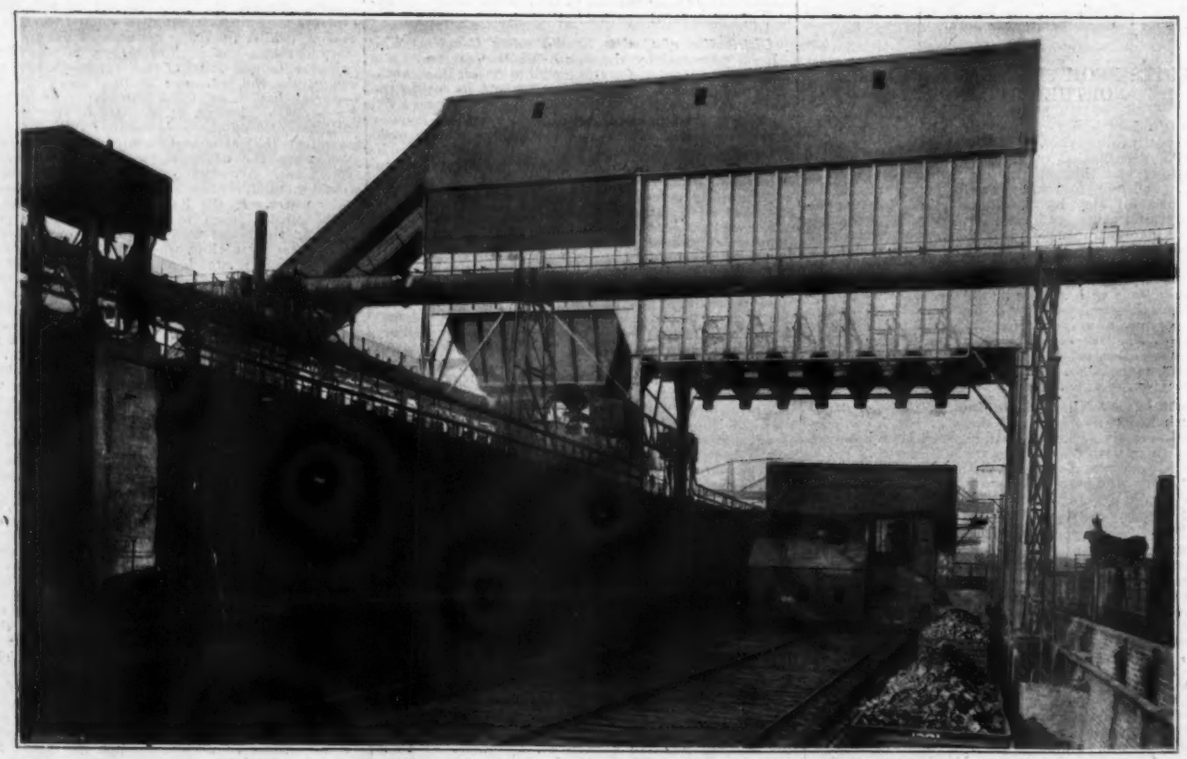

Fig. 22. Back View of Coke Ovens with Overhead Coal Bunkers and Travelling Stamping and Charging Machine.

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Offices for Publication and Advertisements, 35 and 36, Bedford-street, Strand, London, W.C. 2.

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TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3063 and 3506 GERRARD.

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With a Two-Page Plate of the COAL-HANDLING PLANT AT THE SALTLEY GAS WORKS, BIRMINGHAM.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 549.

ENGINEERING.

FRIDAY, MAY 17, 1918.

INDUSTRIAL ACCIDENTS.

IF a good man struggling with adversity be a sight for the gods there must have been rousing times on Olympus whilst Dr. H. M. Vernon was preparing his last report to the Committee on the Health of Munition Workers.* In this report Dr. Vernon has attempted not merely a difficult but an impossible task, viz., to establish from a very limited set of data far-reaching general conclusions as to matters involving a large number of independent variables.

In his previous reports Dr. Vernon has published some very valuable observations on such subjects as the connection between output and hours of labour, and it is greatly to be regretted that the present report has been framed on more ambitious lines. Honesty and intelligent industry suffice for the collection of data, but must be supplemented by other qualities, when such data are to be utilised for establishing effective generalisations. In the present instance the report will not add to the reputation of its author or to that of the department which in these days of paper shortage is not justified in issuing lengthy documents having little intrinsic value.

The object of the investigation described in this report was to establish some correlation between accidents in workshops and such factors as fatigue, productivity, lighting, alcoholism and climatic conditions. The data were obtained from four factories, and the investigation in one case extended over 25½ months, and over shorter periods in the case of the others. The results are for the most part very erratic, and the only generalisations which seem fairly well established are that accidents are fewer on night work than on day work and that cold weather tends to increase the number. The reporter, however, by introducing what he considers to be plausible assumptions as to the effect of factors for which data are lacking, arrives at very far-reaching conclusions indeed, and these conclusions are not put forward as provisional, pending the collection of more adequate data, but as verities positively demonstrated. The whole treatment of the subject is, in short, unscientific.

The report asserts that "speed of production is the essential factor in accident causation," that "a 10 per cent. speeding-up may well induce an increase of 50 per cent. to 100 per cent. in the number of accidents"; yet the statistics given show that whilst production during the night shift exceeded that of the day shift the number of accidents was less. Were Dr. Vernon's conclusion really demonstrated the position would indeed be serious. We have yet to learn, however, that the accident rate in the Ford factories is in any way abnormally high. In view of the animus with which the Ford system is regarded in certain quarters, such an alarming connection between speeding-up and accident rates could hardly have escaped the notice of Mr. Ford's critics. Moreover, there are in this country two large factories employing each about the same number of hands and both turning out 9·2-in. shells. In the one staffed by women the output of these heavy shells is nearly double that of the rival factory, and if Dr. Vernon's view be correct the accident rate amongst the women must be extremely serious. Comparative data as to these two cases could probably be supplied him at the Ministry of Munitions, and the results would form a far more reliable basis for a generalisation than the conflicting results of his own inquiry. As a matter of fact, there is at least *a priori* reason for believing that one effect of speeding-up will be a reduction of the accident rate. Thus a well-known engineer increased the output of a shell factory by some 50 per cent. to 100 per cent. simply by arranging that the blanks were delivered to the lathe hands at hand height in place of at floor level. In another case, a very large increase in production was effected in a heavy shell works simply by putting the labourers "on piece." Each gang of labourers had a certain set of machines assigned to it and was paid on the number of shells produced. As a consequence the men gave thought to their work and took care that no machine ever stood idle for defect of material or for lack of assistance in chucking the blanks. To ensure that the machines and their surroundings were kept in proper condition the management reserved the right to add further men to the gang in case of neglect, thus raising the number amongst which the gang earnings had to be divided. The increase in output thus obtained was very large, but there is no reason for believing that the accident rate, consequent on this speeding-up, was even proportionate to this increase of output, let alone being from three to five times as much, as Dr. Vernon assumes from a contemplation of his data.

It is, of course, highly probable that overstrain is a cause of accidents, but there is no necessary connection between overstrain and productivity. The maximum of output is not attained by overdriving men, but by applying thought to ease their tasks. In some previous reports, Dr. Vernon has shown that production increased in many cases when the hours of labour were reduced. The most notable case was that of a woman who refused to overstrain herself by working the long hours and overtime demanded by the management. Nevertheless, on a month's test this woman showed a higher output than any other employee. If this speedy worker suffered more accidents than her rivals, Dr. Vernon failed to note the fact in his report.

Dr. Vernon again asserts that there is a connection between alcoholic indulgence and the accident rate. This is almost certainly true, but it does not follow directly from the data given in his report. As a matter of fact, after the reduction of supplies of alcohol in 1917 the rate of accidents actually increased, and to bring the facts into accord with his theory, the reporter has to make hypotheses as to the possible habits of the workers. In short, throughout the whole report, if the apparent effect of the figures is in disaccord with the reporter's predilections, some hypothesis to discount the discrepancy is always forthcoming. Tyndall expatiated years ago on the virtues of the scientific use of the imagination; but he would hardly have approved of Dr. Vernon's attempt to exemplify the art.

The lack of a scientific habit of mind is clearly shown in the reporter's assertion that "no doubt the less alcohol the worker consumes the better it is for the *quality* and quantity of his work." As regards quantity we believe Dr. Vernon is correct. When long hours have to be worked on breakdown jobs it is often observed that the teetotaller outlasts the non-abstainer, but there is a distinct lack of evidence that abstinence and the highest degree of excellence in quality are commonly associated. In fact, the works manager often complains that his best workman, the man who can tackle jobs beyond the skill of any other employé is,

* **An investigation of the factors concerned in the causation of industrial accidents. Cd. 9046. Published by His Majesty's Stationery Office. Price 6d.**

unfortunately, given to drink. In fact, quality is a matter not of manual dexterity or of endurance, but of mind. The experimental investigation carried out at the Carnegie Institute in 1915 showed that whilst small doses of alcohol "depressed the simplest reflex actions, such as the knee jerk, the more complex the neural arc involved the less was this effect manifested, whilst in operations involving mental work and memory the effect was either nil or an improvement was noted."* Even as regards matters involving the co-ordination of eye and hand it is noteworthy that Dr. W. G. Grace, though a non-smoker, was not a total abstainer, and in purely intellectual matters the acme of quality is seldom or never associated with total abstinence.

This criticism has been introduced not in defence of the "Trade" but to illustrate the reporter's unscientific habit of mind which inclines him to make positive statements which are unsubstantiated by the evidence which he adduces in his report. His previous reports we have welcomed as valuable contributions to our stock of carefully verified data, and we hope to have to thank Dr. Vernon for much additional matter of this kind in the future.

SILICON AND CARBON.

THE difficulties of the physicist engaged in unravelling the structure of the atom will not diminish as his study advances. When the elements are arranged according to their atomic weights, in horizontal rows, each of eight elements mostly, the members of the natural groups, endowed with similar properties, fall into the same vertical columns. The alkali metals form one of the most characteristic groups, the halogens—fluorine, chlorine, bromine, iodine—another. As each atom of a halogen can replace one atom of hydrogen, they are generally considered univalent; but the chemists know puzzling compounds of the halogens with one another and with other elements, which suggest a maximum valency of seven. Similar relations hold for other groups; valencies are variable and often uncertain, and the chemist accordingly distinguishes various classes of compounds in which the same element appears of different valencies. Carbon and silicon belong to another natural group, which, further, comprises titanium and germanium and the metals of the rare earths, zirconium and cerium, between which tin stands; these elements are considered quadrivalent. The similarity between carbon and silicon has already been pointed out by Wöhler; its importance has long been recognised by metallurgists, and in the last decades a large number of organic silicon compounds have been prepared, so strongly resembling carbon compounds, that "silicon organisms" have been thought of, consisting largely of silicon in the sense that most organisms are chiefly built up of carbon. In this country, Professor Stanley Kipping, of Nottingham, received the Longstaff Medal of the Chemical Society for his share in this work. There is the additional parallel that the external skeletons of the coral polypes and many other organisms, are essentially carbonates, whilst in some sponges, &c., silicates or silicic acid itself form the skeleton material. When we look closer into this relationship, however, as Professor Alfred Stock, of Berlin, has recently done, we meet with both remarkable analyses and strange discrepancies.

When we examine the hydrides, binary compounds of an element with hydrogen, in the first instance, we are struck with the great variety of well-known hydro-carbons, saturated and unsaturated, of different types (paraffins, olefines, benzenes, &c.). Silicon, similarly, forms hydrides SiH_4, Si_2H_6, Si_3H_8, $Si_{14}H_{30}$, &c., but, with the exception of SiH_4 (which corresponds to methane), all these hydrides are very unstable, and catch fire spontaneously. Silicon carbide, SiC, so useful as an abrasive and refractory material is, on the other hand, very stable and when we substitute hydrocarbon radicles for hydrogen in the silicon hydrides, we obtain compounds like $Si.C_2H_5.C_3H_7.C_6H_5.C_7H_7$, which smell and behave like petroleum constituents. The compound $Si(C_7H_7)_4$ is, indeed, distinguished by an extraordinarily high boiling point, as it can be distilled above 550 deg. C. without decomposing. These compounds, moreover, can be nitrated, sulphonated, &c., and are even known in the asymmetric, optically active, condition. The halogen compounds of silicon are more stable than the hydrides, but the silicon compounds of the amine class (ammonia, whose H is replaced by carbon radicles) are decomposed by contact with water. When two silicon atoms come together in the same molecule, the analogy with carbon again fails. Carbon readily enters into long chains or closed cycles (rings), in which one C is linked, by one or more bonds, with another C, but only few and unstable Si compounds of this kind are known. On the other hand, the affinity of silicon for oxygen is very strong, and there are plenty of organic silicon hydroxyls of the alcohol type, though few containing something akin to the carboxyl group CO·OH. The dioxide silica, SiO_2 is the anhydride of silicic acid, analogous to CO_2, the anhydride of the hypothetical carbonic acid (unknown in the free state); but it is very doubtful whether any of the silicates—and silica itself—consist of single molecules, whilst the carbonates are mono-molecular. The compound Si–O–Si seems to differ from Si–Si, which, as we mentioned, does not appear to form chains by the union of several molecules, inasmuch as it polymerises readily, and this tendency to polymerise may account for the high melting points of silica and of silicates.

As regards valency, both carbon and silicon have apparently the same maximum valency 4 for both electro-negative and electro-positive elements. Whilst, however, the affinity of carbon for negative and for positive elements is of much the same order—carbon is indeed conspicuous among the elements in this respect—silicon shows a decided preference for electro-negative elements and groups, such as oxygen, the halogens and organic radicles. Barlow and Pope, however, have questioned the quadrivalency of carbon, and Jerusalem did not confirm the assumed isomorphism of crystallised carbon and silicon compounds. The Röntgen-ray examination again supports the analogy; there seems to be agreement between the space lattices of crystallised carbon (diamonds) and silicon; whether the analogy extends to the amorphous modifications of the two elements is not yet known.

The pronounced affinity of silicon for oxygen, and the circumstance that silicon dioxide, SiO_2, after once having been liberated in the gelatinous condition, and dried to gritty sand, is very inert and practically insoluble, whilst the corresponding carbon dioxide, CO_2, is gaseous and easily reducible, may prove a sufficiently strong bar to the development of any "organic silicon world." The plant inhales CO_2 and converts it into living matter; the SiO_2 absorbed by the animal system finds its way into the hairs, feathers, scales, and other parts of the external skeleton, which are not constantly being resorbed and reformed like the bones and tissues. Thus, the relative irreversibility of the silicon reactions limits their utilisation. Yet the preparation of intermediate silicon hydrocarbons might conceivably attain in scientific ways, what cracking processes attain by crude, wasteful methods. We are not aware that such processes have as yet been technically tried.

* *Nature*, August 3, 1916, page 465.

FIRING WITH COAL DUST.

Many attempts have been made in the past to utilise coal dust as fuel. The Crampton furnaces experimented with at Woolwich in 1873 may be recalled in this connection. One of the difficulties there met with was, we believe, the rapid wear of the furnace linings. Of recent years powdered coal has, of course, become the recognised standard fuel used for rotary Portland cement kilns. Originally, natural or producer gas was used, and later oil, but ultimately powdered coal ousted these competitors. At present the consumption of pulverised coal in the Portland cement furnaces of America is said to amount to about 6,000,000 tons annually. Part of the success of this form of fuel in the cement industry is possibly due to the circumstance that cement makers being accustomed to fine grinding, were ready to properly pulverise the coal before attempting to use it as fuel. Certainly, whatever the cause the cement industry has been the first in which dust fuel has proved an unqualified success. The experience gained here has, moreover, led to the introduction of the system into other industries, some 2,000,000 tons being used annually in American steel works and about three-fourths as much in copper smelting works. It is also being largely used for desulphurising and roasting ores in rotary kilns. Attempts are now being made in America to use dust fuel also for steam raising. In essentials this scheme is, of course, not new. The Perret system of burning dust fuel was fairly well known 20 years ago, but failed to develope. More recently, very good reports have been received as to the working of the Bettington boiler at the Johannesburg municipal power plant though the net boiler efficiency here proved to be a little less than that of the ordinary water tube boiler with which it was compared. Yet the difference was not great and was to a large extent set off by the time saved in raising steam on emergencies. The Bettington boiler, as is well known, is of a somewhat special construction, but in the American installations boilers of a less specialised design are now being fired with dust fuel. The introduction of this method of firing was facilitated here by the fact that many boilers had been erected with the intention of operating them either with natural gas or with crude oil. When difficulties arose as to further supplies of these fuels, it was natural to try and find a substitute which could be used without too revolutionary changes in the furnaces and stokehold conditions. A typical instance is provided by the power house at Parsons of the Missouri, Kansas and Texas Railway. The eight 250 h.p. water tube boilers installed here were originally operated with natural gas or crude oil. When this became scarce, the only coals available were of somewhat low quality containing much moisture and much ash. It was found, however, that in spite of this they could be used satisfactorily in the form of dust and a complete equipment for pulverising and drying the coal was accordingly installed by the Fuller Engineering Company of Allentown, Pennsylvania, and was set to work in the summer of 1916. The results have, it is stated, been most satisfactory.

The pulverising and drying plant is arranged in a separate building. After a first crushing the coal is passed through a magnetic separator to take out casual pieces of iron or steel which might otherwise cause injury to the fine crushing plant. The material as received from this separator undergoes a further rough crushing and is then dried in an independently fired kiln, after which it passes to the fine crushers which reduce it to a state such that 95 per cent. of it will pass through a 100 mesh screen. In this condition Mr. Barnhurst, Engineer to the Fuller Engineering Company, states that the coal weighs from 32 lb. to 38 lb. per cubic ft. and will flow almost like a fluid. It is best handled by screw conveyors running in dust proof ducts. The wear of these conveyors is said to be small as the coal has itself lubricating properties. About 17 h.p. hours per ton of coal treated are expended in the crushing, drying and elevating machinery. The furnace in which dust fuel is to be burnt must, Mr. Barnhurst states, be of very ample capacity. This is required for two reasons. In the first place to ensure that the fuel stays in the furnace long enough to be completely consumed; but a second consideration, and one of greater importance, is that if the furnace is cramped the linings will be cut away by the high velocity of the gases.

At the Kansas plant the volume of the furnaces was increased by building an extension to the front of each boiler. The fuel is fed into the furnaces by a blast supplied by a blower under a pressure of ½ to ¾ oz., additional air being drawn in by the inductive action of this high velocity jet. Each blower is driven by a 10 h.p. motor. Absolutely smokeless combustion is secured. According to Mr. Barnhurst almost any kind of coal can be used, but some of the lignites require a great deal of drying. The best results are obtained with coals having less than 10 per cent. of ash, with volatile matter between 30 and 40 per cent., and with 40 to 50 per cent. of fixed carbon. The sulphur content should be low, although coal containing as much as 4½ to 5 per cent. of sulphur has been success-

fully used for boiler firing. When the moisture does not exceed 5 per cent. to 10 per cent. some 25 lb. to 35 lb. of fuel must be burnt for each ton dried.

THE SPINNING TOP IN HARNESS.

"To those who study the progress of exact science the common spinning top is a symbol of the labours and perplexities of men who had threaded successfully the mazes of planetary motion." With this quotation from Maxwell's "Dynamical Top," Sir George Greenhill, F.R.S., on Friday, May 3, introduced his Royal Institution discourse on "The Spinning Top in Harness," adding that the reference to planetary motion was, he feared, a sly dig at Newton. The subject of the spinning top is full of difficulty, but Sir George was able to deal with it in a way that was interesting both to the mathematician and also to the general members of his audience; although he made use neither of the blackboard nor of formulæ, yet he appealed to the former class by indicating a few lemmas in Poinsot's style and in other ways, and to the latter by unfamiliar demonstrations with apparatus. His tops were of large size, so that their motions could be followed from a distance, bicycle wheels of 28 in. and 52 in. diameter being used for the purpose. The former ran loose on a spindle or axle screwed into a short length of rifle barrel. The distant end of this barrel was connected (Fig. 1) to a fixed support by a universal joint which allowed it to move in all directions, so that the wheel could lie in a horizontal plane, or be raised into a vertical plane, or into any intermediate position. In fact, the bracket used to carry the universal joint was longer and narrower than that shown in the engraving, so that the wheel could be raised until its centre was very considerably above the centre of the joint. The wheel was first spun by hand until it attained a high circumferential velocity and then, when released, it ran steadily round in a circle, the axis being horizontal or nearly so. If during this progressing it received a slight push downwards, it followed an undulating path, rising and falling slightly and describing a series of cusps (Fig. 2).

By a little care in manipulation a great variety of these curves could be produced. Similarly, if the axle were held at an ascending angle, and then were released with the wheel in rotation, the axle would gradually fall through a series of cusps or undulations, until, in one special case, it became horizontal.

Before giving these demonstrations, Sir George had explained the general principles of the motion of a top. He had a 52-in. bicycle wheel running loose on a journal at the end of a bar. It might be likened to a Japanese umbrella, without its paper cover, loose on the stick. This was held by an assistant as a lady might hold an umbrella to protect herself from the attack of a fierce dog. When the wheel was raised, as the umbrella might be raised to protect the throat from the dog, the wheel went off automatically to the right unless prevented by a strong muscular effort. If the wheel was moved to the right, the axle automatically went downwards. This action, the lecturer said, had to be allowed for in the piloting of an aeroplane, since the propeller acted like the spinning wheel, and if the engine were of the Gnome type it added to the gyrostatic effect. Putting the helm to port called up a couple tending to turn the head to starboard and to dip the nose of the machine. To turn the machine to starboard by utilising gyroscopic domination, a horizontal rudder had to be used and the helm be put down vertically. Thus the top in harness was like the Irish pig of Professor J. Perry, which could not be persuaded to accompany its master to the market except by steering him sideways into the ditch. This sideway force was the gyroscopic term in electromagnetic equations.

Proceeding, Sir George stated that modern suggestions of automatic gyroscopic steering control of flying machines and torpedoes under water could be tested with the simple appliances shown. If the axle of the 28-in. wheel were horizontal and the wheel were spinning, the free projecting end of the axle could be held on one finger, and there was the same pressure on the finger as if the wheel were at rest, no gyrostatic action being experienced. But if the axle were released gyrostatic action immediately developed, especially if he attempted to make the wheel swing in a vertical plane like an ordinary pendulum. "Hurry the precession, and the top rises against gravity," was the Kelvin rule, the secret of plate spinning. The cyclist steered intentionally into a smaller circle to recover the vertical position, and that went on incessantly; a bicycle could not run straight. To show the effect of nutation on precession, Sir George tried to beat the rim of the big wheel down with sticks when it was spinning about its vertical spindle; that hardly made it flinch. But projecting the wheel the reverse way of natural precession set up violent disturbances. Repeating Maxwell's experiment of "a top on the top of a top," the lecturer detached the 28-in. wheel of his apparatus and placed its axle into a cup in the end of the vertical axle of the 52-in. wheel, both wheels having previously been set spinning in the same direction about their vertical axes. Many links of such a gyrostatic chain would give a mechanical model of the electro-magnetic rotary polarisation of light,

Fig. 1.

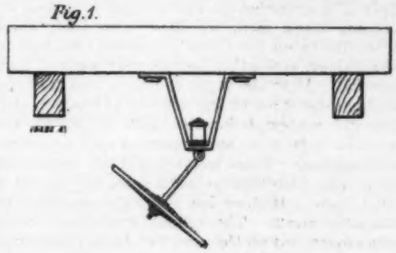
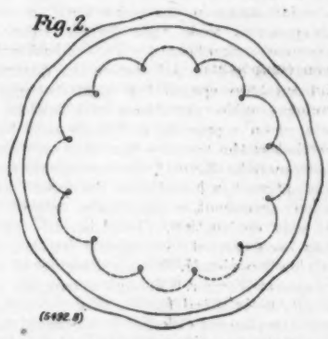


Fig. 2.



Sir George remarked, and he had simplified, in his Report on Gyroscopic Theory of 1914, the elaborate mathematical investigation of these problems by Kelvin.

Proceeding, the lecturer referred to the difference between statical and dynamical balance and stability. In statical equilibrium the centre of gravity sought the lowest position it could find; in dynamical stability of balance it rose as high as it could. A top was said to sleep when spinning steadily upright. Man slept lying down, but for ease of progression he assumed the upright position, he carried rifle, knapsack, &c., as high as possible, and his progress was not more difficult when mounted on stilts. Confusion between statical and dynamical stability of balance had led to serious mistakes, *e.g.*, ballasting a ship too low and thereby making it uneasy among waves, and widening the railway gauge in order to lower the boiler and carriage body between the rails; the centre of gravity of the modern locomotive was high up. The axial stability of flying bullets and shells was obtained by the gyroscopic action of the spin imparted to the projectile by the rifling; no more spin should be given than was absolutely necessary, Sir George insisted; but the calculations were difficult. Even an arrow acquired a certain spin from the reaction between the air and the flexible feathers on its shaft. The Parsons turbine on board ship had to be treated on the gyroscopic theory; rolling did not affect it, but the internal stresses due to pitching had to be investigated. Dynamos mounted with their axes across the ship squealed when the ship rolled. Heavy rolling could be cured by fitting bilge-keels to the ship, at a permanent loss of speed of a knot or two in all weathers. Schlick's sea gyroscope did the same without sacrifice of speed and required little power. The gyroscope consisted of a heavy horizontal flywheel which was controlled by a hydraulic buffer in the line of the keel, the damping action of which was regulated by a valve to suit the period of the waves. But Schlick had felt annoyed, it was said, when his invention had been found more useful still in increasing and maintaining the rolling of an ice-breaker and of a ship working off a sand-bank.

A top spinning in a smooth cup would, the lecturer said, stand upright even if carried about with its cup. A polished mirror carried by such a top would show the mercurial horizon, as had been suggested by Serson in 1744. The Admiralty of that day had not crabbed the idea with the usual "won't work," but had actually sent Serson out on the Victory, which was lost with all hands on the Casquets near Alderney. The idea had been revived by Fléuriais, whose gyroscopic horizon was said to give good results in skilful hands. The most important of these instruments, the gyroscopic compass, had been suggested by Sir William Thomson; it had required the mechanical skill of men like Anschütz and Sperry, however, to construct a steel flywheel, 4 in. in diameter, spinning at 20,000 r.p.m. The axle of this compass sought to keep in the direction of the polar axis, and a card it carried pointed due north undisturbed by magnetic variation; if anyone pushed the card away from its course, however, it would take an hour or more to swing back into place again. Dwelling, in his concluding remarks, on the greatest spinning top we know, the Earth, and its precession, Sir George mentioned that Lord Kelvin had on his yacht amused himself by steering his course on the lines of the advice which the nymph Calypso gave to Ulysses when about to set sail on his raft from Gibraltar: "Never to let the Bear take a bath." Ulysses would take his latitude and position with a piece of string, by holding one end up to the pole, sliding the other fingers to cover some well-known star and sweeping the hand round to see if the star would graze the horizon; the observation was repeated with another star. But, owing to precession the pole had, since Homer's days, described more than a tenth of its circuit of 26,000 years, and Calypso's rule would now land a sailor some 600 miles into Africa.

NOTES.

THE BOHR MODEL ATOM.

In a paper read before the American Institute of Electrical Engineers, Dr. A. C. Crehore gives the results of a critical examination of the Bohr model atom, taking into account certain factors neglected by Professor Bohr, and these he finds make necessary substantial modifications in the model. According to Bohr's hypothesis an atom is a structure composed in part of a charge of positive electricity the centre of which is the geometric centre of the atom. This positive charge is extremely concentrated. Around this positive nucleus are rings of electrons describing approximately circular orbits, the diameters of these orbits being very large as compared with the size of the electron. The total positive charge at the centre is equal to the sum of all the charges of the revolving electrons, so that the atom as a whole is neutral. On Bohr's theory an electron may move from one orbit to another, but the number of possible orbits is supposed to be limited, so that an electron having left one of these limited number of orbits, moves to another of these orbits in a sudden jump, and cannot revolve in an orbit of any intermediate diameter. In making this passage the kinetic energy of the electron changes, and it is assumed that this change is in all cases an integral multiple of Planck's quantum. The atoms thus radiate energy when they fall in towards the nucleus and absorb it if the transfer is effected in the opposite direction. There is no radiation at all so long as an electron does not change its orbit, although all the electrons are in rapid motion. Dr. Crehore has worked out the complete mathematical solution of the problem of finding the force that one electron revolving at a uniform rate in a circular orbit exerts upon a second

electron revolving in a different circular orbit. In the simplest case both electrons revolve in the same orbit at opposite ends of a diameter of the circle of which the positive nucleus is the centre. The total radial force on the electron, Dr. Crehore finds, is then expressed by three terms, one of which depends entirely on the motion of the ring. This term is a repulsive force varying inversely as the third power of the radius and directly as the fourth power of the velocity. The equilibrium is stable only when the radius is about 2×10^{-10} cm., or about $\frac{1}{100}$ of the value according to Bohr's theory, in which the forces due to the motion of the rings of the electrons were neglected.

Canadian Nickel-Copper Steel.

The famous nickel-copper deposits of Sudbury, Ontario, Canada, at present the principal source of the world's nickel, promise to provide us with nickel-copper steel, rivalling nickel-steel in many respects. That would be a great step in advance, and not only for Canada, which has not so far profited from its wealth in nickel ores to the extent it should profit. The deposits form a basin, 36 miles long by 18 miles wide, which was discovered early in the 'eighties, when the Canadian Pacific Railway was cut, and are owned by several companies. The Canadian Copper Company, first established, sent its ores to the Orford Copper Company, of Constable Hook, New York, until the two amalgamated to the International Company, which has now a refinery at Port Colborne, Ontario. Later, the Mond Nickel Corporation and the British-American Nickel Corporation entered the field. The different companies work different processes, but they all practically stop at the production of a matte, which subsequently goes to the United States or to England. The ores are roasted in open heaps and smelted down to mixed sulphides of iron, copper and nickel; this matte is then Bessemerised to eliminate the iron and to obtain a final matte, richer in copper and nickel, retaining also the platinum and palladium and other precious metals of the ores. Many hundred tons of sulphur are burnt to waste per day in the roasting, the fumes desolating the district, and thousands of tons of iron pass into the slags. Numerous attempts have been made to produce alloys of nickel, copper and iron in the furnace. All the inventors, except Shuter, endeavoured to select ores poor in copper, being under the impression that copper was undesirable in steel. Recently, we see from a paper read by Mr. R. W. Leonard before the Canadian Society of Civil Engineers, G. H. Clamer, of Philadelphia, has used a monel metal (a natural alloy of Ni-Cu from Sudbury ores) in the manufacture of a steel, which is utilised for making armour-piercing shells, and Mr. George M. Colvocoresses, late of the Orford Company, has succeeded, by patented processes, in smelting Sudbury ores, or the slags of the present processes, into nickel-copper steel (Nicu-steel), in which copper to a certain extent replaces nickel with the same or similar beneficial effects. The experiments of the latter were conducted in the plant of the Canada Cement Company, at Montreal, with 200 tons of ore and 40 tons of slag from Sudbury, under the supervision of Mr. H. A. Morin, a former colleague of Mr. Colvocoresses. The ores contained about 40 per cent. or 50 per cent. of iron, 3 per cent. or 4 per cent. of nickel, 1 per cent. or 1½ per cent. of copper, 25 per cent. to 30 per cent. of sulphur, besides silica, alumina, lime and magnesia; the slag was slightly richer in nickel and copper apparently, much poorer in sulphur, but much richer in silica. We do not reproduce more figures, since the paper forwarded to us evidently contains misprints difficult to check; neither the ores nor the slags were fresh, but had been weathering for many years in open heaps. The ores were roasted in a reverberatory furnace for 5 hours; the roasted ore was mixed with lime and coke breeze or coal, the high silica content calling for much lime in an electric, open-hearth steel furnace which, it is said, was not in very good condition. The slags were treated similarly, and in their case the 2·2 per cent. of sulphur were reduced to 0·065 per cent. Altogether 107 large ingots, each of 175 lb., and 60 smaller ingots were obtained, and the pig-iron produced contained 3 per cent. of carbon, 2·2 per cent. of nickel, 0·4 per cent. of copper. That the copper can replace nickel in steel is largely acknowledged now, and the presence of copper seems to impart a greater uniformity of composition and lesser liability to corrosion to the steel. The mechanical tests made by the Nicu-Steel Corporation look on the whole very satisfactory, and there are independent, favourable reports by Dr. A. Stansfield and Professor G. A. Guess. It will be interesting to watch the development of this alloy.

LITERATURE.

La Campagne Anglo-Belge de l'Afrique Orientale Allemande. Charles Stiénon. Preface de M. le Baron de Broqueville, Ministre de la Guerre de Belgique. Avec 46 Illustrations hors texte et 2 cartes. Paris: Berger-Levrault, 1917. [Prix, 6 francs.]

As the consequence of a gross act of perfidy on the part of Frederic the Great, perpetrated to enable him to reap the advantages attending the discomfiture of a sovereign he was pledged to defend and succour, black men, we have been told, fought to the death on the Coast of Caromandel, and red men scalped each other on the great lakes of North America. After the lapse of nearly two centuries, an equal disregard of the sanctity of treaties, and a profound contempt for the rights of others, have produced acts quite as undeserved and as ruthless in character. Time has brought no mitigation, for in war outrages increase with the power to inflict them. History has not only repeated, but intensified itself. The crimes committed around Kilimanjaro and on the banks of Lake Tanganyika, districts as remote from the initial struggle as were India and Canada in the olden time, have been re-enacted on a scale that dwarfs those puny conflicts to insignificance. The inhabitants of Central Africa had no interest in the quarrel, and might have been spared the wanton barbarities, that ungovernable ambitions and lawless force precipitated on a peaceful and inoffensive folk.

Nevertheless the country has been overrun and wasted from Lake Kivu to the Portuguese frontier, and the native has learnt how Europeans conduct war when armament is practically unlimited and science aids destruction. This distant campaign that has been carried to complete fruition within the last few months, M. Stiénon describes in a lucid and temperate manner. Though apparently a non-combatant, he is fitted for his task by being well versed in the plans of Colonial development, and he views in a proper perspective the whole series of events that have marked the struggle in the so-called German East Africa, since 1914.

Short introductory chapters describe the manner in which Germany and Belgium acquired spheres of influence on the African Continent, where the Home Government of the latter was playing a worthy part in the civilisation of a large district, facilitating its progress and developing its resources. By the policy adopted since 1908, Belgium not only consolidated her possessions, but increased the respect and cordiality with which she was regarded in Europe for her consistent regard of treaty rights and her firm determination to maintain her position as an independent unit in the international community. The treaty of Berlin of 1885 apparently guaranteed the neutrality of the Congo Basin, the high contracting parties to that treaty pledging themselves in the case of war in Europe to regard the entire zone as under the law of neutrality, or as belonging to a non-belligerent. The general clause clearly enunciates the obligation: "les parties belligérantes renonceraient, dès lors, à étendre les hostilités aux territoires ainsi neutralisés, aussi bien qu'à les faire servir de bases à des opérations de guerre."

Notwithstanding this full and complete abnegation, immediately on the outbreak of hostilities, the Germans were prepared to assume in Africa the bullying attitude that had served them so well in Europe. On August 8, 1914, M. Poincaré informed Baron Guillaume, the Belgian Ambassador in Paris, that he believed acts of war had been perpetrated in Ubanghi. Acting on this information, the French Government begged the Spanish Embassy at Berlin, then entrusted with French interests, to demand a proclamation of neutrality in the Congo Basin. In spite of this invitation, or in consequence of it, the Germans assumed a more minatory attitude, and Colonel Tombeur, Vice-Governor of Katanga, was obliged to advise the Belgian Colonial Minister that on August 22 German troops had attacked the port of Lukuga. The Germans have been guilty of so many acts of baseness since, that this episode, of so long ago and so far removed from the main theatre of war, is little remembered, but as an unwarrantable act of aggression it should be set in bold relief. As evidence of calmness and impartiality on the part of the author, it may be mentioned that he records this deliberate breach of treaty rights almost without comment, his object being to give a dispassionate account of well documented facts, on which unprejudiced judgment may be founded.

In the light of later events it becomes clear that Germany had purposed the creation of an extensive economic area in the Congo Basin, that should extend from the Indian to the Atlantic Ocean, thus constituting a solid and permanent wedge driven between England's several possessions, rendering them weak by segregation. With the thoroughness that characterises German proceedings, this policy had been successfully pursued: the pressing manner in which rail and water communications were urged is the natural and visible consequence of this masterly, if selfish, policy. The ultimate aim so clearly perceived, and so energetically pursued, was to escape from the isolated *enclaves* in either East or West Africa that assigned to the Germans an inferior position and to compel England to recognise Germany as an equal Colonial power by forcing a new re-arrangement of African territory entirely in German interests.

To grasp the full meaning of German policy, necessitating for its due fulfilment a lavish expenditure on such constructive works as harbours and railways, assists the judgment in gaining a clear insight into the objects of the campaign, and the character of the strategy that was forced upon the combatants. The author's description of this tangled skein of intrigue and adroitness is lucid and consecutive, and shows how the dangers of a difficult situation were increased by ingenuity and careful preparation. Many problems in this connection, on which definite information would be desirable, are of necessity left unexplained, and for the present they must be left open questions. M. Stiénon writes of events that are too recent; government departments have by no means disclosed all their secrets. For instance, we should like to know whence the Germans procured their munitions of war of which they seem always to have had a sufficiency. The big guns salved from the Königsberg were amply supplied, and the same can be said of the smaller pieces and the machine guns. Apparently more ships must have successfully run the blockade than we suspected, and considering the difficulties of transport through a country ill supplied with roads, the point of disembarkation must have been well selected and probably near the railway terminus. The secret was not penetrated. Wolff's Agency told of two ships that without difficulty, early in 1915, avoided our squadrons on the look out for such craft, and probably there were others to which it was not desirable to call attention. One of these elusive steamers carried not only shells and cartridges, gun carriages for the artillery removed from the Königsberg and a great quantity of manufactured equipment, but also the tools and workmen to fit out a small arsenal, to provide munitions in the colony itself. Apparently, too, supports were carried for the divisions in the field, as otherwise it is difficult to understand how the comparatively small white force sustained itself in a climate that takes a heavy toll of European life, and where wasting fevers sap the energies of the survivors. The Germans knew how to make the most of the natives, a class who whether employed as porters or combatants, were immune from many of the ills from which the white population suffered.

Possessed of a definite, if unscrupulous, policy and amply supplied with the means of putting it into execution, the enemy were able to seize the initiative and to submit the allies to the inconvenience

and loss of sudden invasion. For many weary months the Allies had to withstand the adversary's attacks without much opportunity for replying, for at the outset their united forces amounted to no more than 8,000 soldiers of all ranks wherewith to meet an active enemy supported by five times that number, with the additional advantage of operating on interior lines. Our forces were adapted to meet, or to overawe, native levies: they were not planned to meet the equipped and trained armies of Europe. Behind the extremely thin curtain of defence which this exiguous force provided, the Belgians and English had not only to devise the means of parrying the heavy blows struck by an active and ruthless enemy, but to organise victory. Such was the task that confronted the Allies, and the author essays to tell how effectively that task was accomplished.

If M. Stiénon had no share in the military operations that culminated in the occupation of Tabora, he may be the better qualified to describe them. The area covered is so vast that each section could only have been aware of its own hardships and its own successes. The sense of proportion would have been lost. He is better able to survey the wood as a whole because he is not himself among the trees, but he knows perfectly well how each tree obscures the view, and what obstacles each serves to hide. Two broad issues are constantly before him: the magnitude of the effort to which Belgium was called and the maintenance of tactics by which independent units were made to converge, both in time and location, in order that particular effects should be accomplished with the smallest expenditure of means. It is right and just that we should clearly conceive what Belgium, deprived of home resources, of material, of money and of men, has achieved in this distant scene, because by her actions and enterprise she has shown herself to be endowed with those qualities which fit her to be entrusted with the duties of colonisation. No fear need be entertained that stagnation and indifference will mark her administration, for no more depressing circumstances can be imagined than those over which she has triumphed and deserved to triumph. She has shown herself to be a worthy colleague of the most progressive of all colonisers. To quote the inspiring words of M. de Broqueville, Minister of War, "Elle a montré par ses actes qu'elle était digne, en Europe comme en Afrique, d'assumer toutes les responsabilités de la souveraineté: pour remplir pleinement le rôle difficile qui lui est dévolu dans l'intérêt de la paix du monde, pour le remplir avec fierté, avec confiance, en pleine possession des éléments indispensables au succès, il lui faut une Colonie, et les désastres qui abreuvent la patrie ne font que renforcer ma foi dans la politique dont j'ai toujours été un défenseur convaincu."

War in Africa is not to be judged from a European standpoint. New scales of comparison are needed. For the first time, white has met white on the black man's territory, and military measures have been conducted on a scale comparable to European contests previous to the last gigantic holocaust. Other previous experiences have been confined to actions when the resources of civilisation have encountered the untrained forces of barbarism, and the issue has never been in doubt. The author has had to construct the mise en scène anew, to make us appreciate the vast distances, the imperfect means of communication, the obstacles introduced by the remoteness of the sources of supply. He makes us understand what difficulties have to be surmounted in placing a hydroplane on the waters of Lake Tanganyika, what steadfastness is required in attacking and conquering a German colony five times the area of the mother country. And above all we have to appreciate that the climate is an enemy whose fierceness never relaxes. The cattle drop helpless before the attacks of the tze-tze fly, and the great insect world breeds fevers in man more fatal than Prussian bullets. To render the task of explanation more difficult the author could know little of German strategy. Astute generalship on the enemy's part decided him to refuse a general engagement; he was content to let the Allies waste their resources in following him, well knowing that the climate and fever fought on his side.

Doubtless the picture will have to be redrawn when more details are known, but the author has done his work well with the materials at hand. He emphasises the dangers of a frontal attack, and the reason for adopting enveloping tactics. We can estimate the hardships borne by the men as they forced their way through dense jungle, where lurked unknown dangers, while the sun beat down fiercely and the troops were without water. Doubtless there were many mistakes—inevitable mistakes—from other sources we know there were, but there was no great military disaster, and if we read a little between the lines we may congratulate ourselves on this result. Numerous were the commands, Belgian and English assembling from all points of the compass, but when we find the soldiers of Molitor in touch with those of Sir C. Crewe, and the infantry of Moulaert encountering our own men under General Simson, we feel that the author is justified in saying "Ainsi se précise sur le terrain même l'idée maîtresse de notre stratégie: l'encerclement progressif des Allemands, qui restera un exemple mémorable de liaisons effectives réalisées à travers un territoire immense, sauvage et sans aucune communication naturelle. Il n'est pas inutile d'y insister, car c'est bien là que se trouve la note originale de toute l'entreprise."

Here we leave the story and the author, but we hope we may meet again, when in a new chapter M. Stiénon will tell us how the Germans ignominously quitted the last of their colonies, to seek a brief respite in Mozambique.

Operation and Maintenance of Irrigation Systems. By S. T. HARDING, Assistant Professor of Irrigation, University of California. New York: McGraw-Hill Book Company; London: Hill Publishing Company. 1917. [Price 10s. 6d. net.]

ACCUSTOMED to a humid climate in which the rainfall is distributed with fair uniformity throughout the year, we are not pressingly concerned with the problems of water storage and irrigation. It is true that India and Egypt offer opportunities for our irrigation engineers, but in this work the author confines his attention rigidly to American systems, which prove sufficiently engrossing. Almost as disinterested spectators, we have admired the energy and the skill with which the engineers of the United States have carried to a successful issue the proposed schemes for irrigation and the reclamation of waste land. At a time of world shortage we can more fully appreciate the foresight and the enterprise that have created an army of agriculturists and practically added another State to the Union. The enormous figures telling of work accomplished fail to impress, and we have only a faint notion of the grand scale on which America has planned to make the arid plains of the Far West productive and fruitful. The gigantic proportions of the Roosevelt Dam on the Salt River, that provides a reservoir capacity of 1,500,000 acre-ft., speak only a little more adequately of the magnificence of the effort. The lofty dam on the Boise River, Idaho, the highest structure of the kind in the world, is another landmark to compel our respect for the scale on which America works, and to remind us what the Reclamation Service has achieved to increase the world's supplies.

But construction, though in itself attractive and stimulating, is only the beginning of the work. Sustained effort on less heroic lines is necessary if the reward is to be reaped for which others have laboured. Professor Harding has no exciting tale to tell in which mammoth projects are described and huge schemes outlined. He has to show that watchful management and careful maintenance are necessary to ensure success and to insist on the importance of small details. He is here addressing students who may be engaged in the Reclamation Service; the volume is the outcome of notes prepared for a series of lectures given to students in the University of California, but they might be studied with profit by the farmers on irrigation lands. The problem of settlement on such land, and of the successful utilisation of the water brought within reach, is not simple, and if the scheme is to be commensurate with the outlay, to say nothing of the high hopes entertained from the social side, each party to the contract, the provider and the user, has to exhibit mutual forbearance; a forbearance that is easier exercised among the instructed. The professor is not only providing facts, though these are plentiful enough; he is giving lessons on the tactful management of men. Those he is immediately addressing will be responsible for the protection of interests that may appear antagonistic to those of the irrigators, and their action is liable to be criticised both by the water owners and the water users. And those who may think that the work of irrigation is easy, that it solves all the difficulties of agriculture, have much to learn, especially as is often the case they take part in the struggle with little or no experience. With the water brought to the edge of his farm, and possibly in excess of his needs, the occupier has much hard work in clearing, ditching and grading his land to receive the water, which must be skilfully handled if loss and damage are to be prevented. If the harvest or return is thought to be inadequate, the pioneer will hardly be persuaded that his methods, or want of method, are to blame, and unjust charges are likely to be levelled against the water authorities. Professor Harding has something to say on the treatment of "complaints" that indicates the competent man of the world as well as the irrigation engineer, but even the judicious handling of discontented settlers may not prevent the unpopularity that follows on the trail of pecuniary loss and disappointment. It must be remembered that there is no test or qualification for settlers on the reclamation projects. Any citizen who has not exhausted his homestead right may take up a farm unit. The Reclamation Service may be congratulated that with so little experience on the part of either the provider or the user of irrigating water the scheme has worked successfully with but little friction. In 1914 the farmers on the Government projects harvested irrigated corps from over 700,000 acres, of the value of 16,000,000 dols.

It will be admitted that the management and operation of irrigation works embracing in their entirety 1,500,000 acres present no simple problem, and that systematised information and experience is of the last importance. Professor Harding is to be regarded as a pioneer attacking a difficult proposition. He can avail himself of very little co-ordinated material. Partial discussion on many points of local interest has been published in serials, but probably it is correct to say that no deliberate attempt has been made to focus the scattered information into a closely reasoned narrow compass. The author aims at giving the general principles that should guide thorough and intelligent management of a complete unit, indicating that local conditions may call for variation in practice. His theme is the unexciting daily routine, the attention to small details that secures efficient management, the careful supervision of the whole machinery that is necessary for success even in the most carefully designed scheme.

He first considers the canal banks subject to the injurious effects of erosion and silting, evils that may be aggravated by vegetation and aquatic growth. Those who have given little attention to the subject would underrate the mischief that can be wrought in the banks by burrowing animals, and the expense entailed in dealing with this nuisance. The pocket gopher has a wide range of habitat and is most abundant where the soil is most fertile. Its burrows give rise to points of weakness at which canal breaks may start, and though the animal is no larger than a rat, the repairs of breaks caused by his activity, particularly in the laterals, may be the largest single item in the cost of canal maintenance.

The serviceable life of wooden structures on irrigation plant has a wide interest; many hydro-electric installations are employing wooden flumes and wood-stave pipe with apparently good results, but whose use has not been sufficiently protracted to furnish trustworthy data concerning the degree of permanence to be expected under the varying conditions in which different kinds of timber are employed. In the case of flumes the period of serviceable life for cedar or redwood may extend to twenty years; fir will probably last for twelve or fifteen years, but pine only eight or ten. Though flumes may be used longer, the annual cost of repair in the later years of use generally make their

retention unprofitable. The life of wood-stave pipe depends much on the conditions of use. Fir, well coated and buried in tightly pressed soil, has an available life of probably more than twenty-five years, but if uncoated, and buried in loose soil, permitting the air to penetrate easily, the life will be shortened from four to seven years. Experience with concrete in irrigation works is insufficient to determine the rate of depreciation, but it has already been found that certain forms of alkali have a deleterious effect, though the nature of the action is at present obscure. In the original Reclamation Law, it was contemplated that the costs of the project might be refunded from water renters in ten annual payments. Later legislation carried through in 1914 spreads the repayment over twenty years, but in either case the length of life of the materials of construction is an essential matter. It may be said, too, here, that as provision is made for the profits of the undertaking to revert to the Reclamation Fund, to be employed in other similar projects, the economical management of the plant already in use acquires a national importance.

The description of the organisation for operation and management necessarily introduces the human element, and we make the acquaintance of the ditch rider, a very important functionary. His duties are as manifold as they are indispensable. He comes in daily contact with the farmers, patrols the canals and supervises the delivery of water. On the capacity and tactfulness of these riders depends much of the success of the scheme; on the judicious distribution of their duties, and the number maintained, its economic working. It is not surprising to read that the personal staff is greatest on Government-controlled works. The author explains this apparent extravagance as due to the preparation of the more elaborate accounts demanded by Government regulation, and the enforcement of a more detailed control of delivery of water than is usual in privately-owned systems. "Such Government projects," writes Professor Harding, "are subject to the inherent disadvantage of all Government work, where the lack of direct responsibility to those actually supplying the funds from their own resources makes the incentive for economy less direct." Let the explanation be what it will, the European reader will not be unacquainted with similar examples in Government-controlled undertakings.

The methods adopted in delivering and measuring water are fully detailed, and the conclusion at which we have arrived from the study of these chapters is, that the task of furnishing each farmer with the quantity of water to which he is entitled, at the time at which its use is desired, is sufficiently formidable. Three methods of delivery are employed—the character of each is indicated by its name—(1) continuous flow, (2) rotation, (3) delivery on demand. All three may be employed at different times on the same system, but the number of variables that enter into the problem is so great that by no possible manipulation could uniform and consistent benefit be secured to all. The varying porosity of the soil, the gradient of the ground, the nature of the crops, their different dates for maturing, and many other factors enter that will give different values to the water supplied at a particular time or to a particular individual. With such variations, there is little reason for suspecting the ditch riders of favouritism, though such charges are made, and one can easily understand that a disappointed farmer believes himself the victim of partiality.

It is impossible to follow the author through all the technical difficulties attending the measurement of irrigation water or the devices that have been arranged to minimise the loss that may follow a temporary shortage. These, like the fiscal conditions, have mostly a local interest, and do not influence the broad outlines of the scheme that the United States contemplated when irrigation became a part of the national programme. Drainage is on a different footing. In any scheme the removal of excess water is as necessary as a sufficient supply. No crop will thrive if the interstices of the soil are filled with water, hence measures must be taken to prevent irrigated lands from becoming seeped and waterlogged. The problem is one that requires intelligent and careful handling. It would seem that drains are not usually constructed until actually needed, or that the evidence of deterioration must be apparent before the remedy is applied. This is not the only disadvantage; the extent of the work to be done cannot be accurately gauged till the water has been in use for some time, and the occupier may be subjected to an uncertain expense. Compulsory drainage is only enforced on that part of the area that is injured. Consequently the high lands whose deep percolation losses have contributed to the injury are exempt, and the owners do not pay for the evil occasioned. If correctly understood, this is inequitable, and would suggest that the drainage scheme was not worked out with the thoroughness that mark the constructive details. The author's comment, that possible future drainage should be kept in mind when the location of irrigation canals is planned, strengthens this view.

In conclusion, we must congratulate Professor Harding in presenting the working of a complicated scheme with great clearness, and as far as we are in a position to judge, with completeness. In describing a number of details, the interest might have been lost by wide distribution, but the skill of the writer has avoided this danger. Never perfunctory, and always severely practical, the book acquires additional value by incorporating the views of those who are responsible for the management of many systems under varying forms of organisation.

Mining and Mine Ventilation. A practical Handbook on the Physics and Chemistry of Mining and Mine Ventilation. By JOSEPH J. WALSH, Mine Inspector, Wilkes Barre, Pa. Illustrated. London: Constable and Co. 1917. [Price 8s. 6d.]

THIS is a practical book intended to assist those who desire to qualify for positions of fireman or examiner under the Coal Mines Regulation Act, 1911, or similar legislation, and we regret that the author has not adhered strictly to the discussion of practical details, a task for which we have no doubt he is eminently qualified by training and experience. Of the extent of the qualifications required from candidates for such posts in America we know little, but in this country the full certificate is granted to those applicants who can satisfy that they are competent to test for gas with a safety lamp, can detect a 2 per cent. "cap," measure an air current and perform similar necessary details. The demands do not appear to be exacting, but present difficulties to those who have had no scientific training, and he is doing very useful work who endeavours to remove the obstacles out of the road of a worthy class of men. But there is little scope, as there should be little desire, to make excursions into the realm of pure science. The more strictly the contents are adapted to the capacity of firemen, the more successful is the handbook likely to prove. Of course, if it were possible to furnish the mental training that the logical and systematic study of any branch of science offers, one would welcome the attempt. In this case, however, it were better to admit frankly that the object sought is simply to enable a student to pass a technical examination, forbearing to burden the memory with a few isolated facts, or vague chemical formulæ, whose painful acquisition can be no effective substitute for methodical scientific education.

The candidate, we venture to suggest, will have no better idea of "matter" or of "force," after reading the author's attempts at definition, than he had before, nor will he be better equipped for passing a technical examination. He will be fortunate, if he is not discouraged by finding additional stumbling blocks put in his way. For in presenting a fragmentary collection of definitions and elementary principles, some inexactnesses of expression will usually be found, and such are not wanting in this treatise. For instance, we have not been able to grasp the meaning of the first paragraph of the book in which matter is defined or described, and, later, the definition of an atom requires some qualification. The author is under the impression that the method of finding the atomic weight of an element is explained in Chapter VI, but no experimental method is given in that chapter.

On those grounds, and some others, it is a pleasure to be quit of these elementary explanations and to turn to the practical matters which occupy approximately one half of the book. The description of the all-important "cap" of the safety lamp formed under certain conditions is quite satisfactory, though we could have wished some mention had been made of Liveing's firedamp indicator, Professor Clowes' hydrogen lamp, and other devices for showing the presence of small quantities of firedamp. The method of measuring ventilating currents is very fully explained, and the description of fans, as well as the numerous examples supplied, should prove very instructive to the candidates who have to struggle unaided through these recondite matters.

It may be a surprise and a disappointment to some to find that throughout the book there is no mention of "mining," notwithstanding the title. Of the actual winning of coal, the sense in which the word "mining" is used in this country there are no details, and in preparing another edition, and the demand for these treatises is very great, we should recommend the addition of some description of the general principles, even if it should necessitate the elimination of some of the formulæ and theory which do little to advance the genuine requirements of those for whom the book is written.

BOOKS RECEIVED.

La Machine Locomotive. Par EDOUARD SAUVAGE. Sixieme edition. Paris: Ch. Beranger.

Glossary of Aeronautical Words and Phrases, with English-French Terms and Metric Equivalents. London: *Aircraft*, 69, Bishopsgate-street. [Price 1s. net.]

The Theory of Electricity. By G. H. LIVENS, M.A. Cambridge: The University Press. [Price 30s. net.]

The Practical Engineer Electrical Pocket Book and Diary for 1918. With Buyers' Guide in French, Spanish and Russian. Nineteenth Year. London: The Technical Publishing Company, Gough-square, E.C. [Price 1s. and 1s. 6d.]

Canada; Department of Mines. Preliminary Report of the Mineral Production of Canada during the Calendar Year 1917. Prepared by JOHN MCLEISH, B.A., Ottawa: J. de Labroquerie Taché.

University of Illinois Bulletin, Vol. xiv., No. 42. Bulletin No. 100. *Percentage of Extraction of Bituminous Coal with Special Reference to Illinois Conditions.* By C. M. YOUNG. Urbana: The University of Illinois; London: Chapman and Hall, Limited.

Keighley Association of Engineers. Report and Lectures, 1916–17. Keighley: Ogden and Shuttleworth, Russel-street. [Price 6d.]

The Fundamentals of Manufacturing Cost. By LAWRENCE R. DICKSEE, M.Com., F.C.A. London: Gee and Co. (Publishers), Limited. [Price 1s. 6d. net.]

A Question of the Day; Public Libraries, their Present Position and Future Development in National Reconstruction (Report of Library Conference). London: Published by the Library Association, Caxton Hall, Westminster. [Price 1s. 6d. net.]

Finding and Stopping Waste in Modern Boiler Rooms. Vol. II. Philadelphia: Harrison Safety Boiler Works. [Price 1 dol.]

The Principles of Urban Traffic. By H. W. D. STONE. London: Crosby Lockwood and Son.

The Excess Profits Duty and Profits of Controlled Establishments. By SPICER AND PEGLER, Chartered Accountants. Third edition, revised and enlarged. London: H. Foulks Lynch and Co., Limited, 61, Wa..ling-street, E.C. 4. [Price 7s. 6d. net.]

Smithsonian Institution. Report on the Progress and Condition of the United States National Museum for the Year ending June 30, 1916. Washington: Government Printing Office.

Transactions of the American Society of Civil Engineers. Vol. lxxxi—December, 1917. New York: Published by the Society.

The Shipping World Year Book, 1918. Edited by EVAN ROWLAND JONES. London: The *Shipping World* Offices. [Price 10s. net.]

The Year Book of the Scientific and Learned Societies of Great Britain and Ireland. London: Charles Griffin and Co., Limited. [Price 9s.]

Elements of Industrial Chemistry. By ALLEN ROGERS. London: Constable and Co., Limited. [Price 12s. 6d. net.]

THE ENGINEERS OF H.M.S. VINDICTIVE.—We are glad that the Admiralty have so fully departed from a practice too often characteristic of their public communications, and have announced the names of the engineers who were responsible for the machinery of the Vindictive when she blocked the Ostend Harbour. There is no need to enlarge to our readers on the heroism demanded of such a venture, because the engineers had to stand by the machinery to the last. The officer in charge was Engineer Lieutenant-Commander Bury, who was severely wounded. He had been in the Vindictive in her attack on the Zeebrugge Mole, and had urged upon the Vice-Admiral his claim to remain in her, with four engine-room artificers, in view of his, and their, special knowledge of the machinery. The names of the four artificers are: H. Cavanagh, H.M.S. Vindictive, wounded; N. Carroll, Royal Naval Barracks, Chatham, wounded; A. Thomas, H.M.S. Lion, missing; H. Harris, H.M.S. Royal Sovereign.

INDUSTRIAL NOTES.

A WHITE PAPER has now been issued by the Board of Inland Revenue entitled "Income Tax. Statement respecting allowances for wear and tear and obsolescence of plant and machinery." Officially it is a "Memorandum"; that is, it conveys information and not instructions. The section (12) of the Act of 1878 on which the present practice is based is quoted, and this Act clearly leaves the Commissioners to make such allowance "as they may think just and reasonable." The next Act, passed in 1907, limits the allowance so that the total, year added to year, shall not exceed the cost of the machinery or plant. On the other hand it enables, in case of the profits being insufficient to provide for depreciation in any year, the allowance to be carried forward and deducted from the profits of succeeding years. The other Acts, 1916 and 1917, refer to repayments in controlled establishments. A schedule of what is called "agreed rates of depreciation" is given, but is "subject to the concurrence of the respective bodies of Income-Tax Commissioners." The rates are 3 per cent. on electric cables and gasholders; 5 per cent. on engines, boilers, main shafting and machinery generally; 7½ per cent. on flax-spinning, flour-milling, printing and saw-milling machinery; 10 per cent. on gas meters, cookers and fires and printers' type; 20 per cent. on motor omnibuses (rate to be reconsidered in 1920–21); 20 per cent. on traction engines, tractors, motor cars and haulage plant, but only if used by timber merchants, sawmillers and manufacturers of timber goods. The 20 per cent. on motor omnibuses has a footnote: "This rate does not apply to commercial motor vehicles." All the foregoing rates are on the written-down values. Rates of 3 per cent. on sailing ships and 4 per cent. on steamships are on the prime cost. It is important to note that this schedule of rates does not apply to the machinery mentioned generally, but only to such machinery when used as capital in specified industries. The engineering, shipbuilding, building, mining and metal industries are not within the schedule at all. It would be advisable for engineering and other firms to obtain copies of the paper, which may be ordered as "Cd. 9022." The price is 1*d.*, plus postage.

The Committee on Production have issued their award on the claim for an advance of wages to dock labourers in London, referred to on page 527 *ante*. The claim was put forward by the National Transport Workers' Federation on a national basis and included a claim for the payment to the men concerned of a bonus equivalent to the bonus of 12½ per cent. granted to munition workers.

The award of the Committee in settlement of the claim submitted to them is:—

Where the war advances already given to the men concerned are 5*d.* per hour and upwards, there shall be paid such further increase as shall bring the total war advance up to 7*d.* per hour. Where the war advances already given amount to less than 5*d.* per hour there shall be paid a further war advance of 2*d.* per hour. Daily workers and weekly workers shall receive advances proportionate to those granted under this award to men paid at hourly rates. Extra payments, if any, made for overtime or for night work, or for Sunday work, shall continue to be calculated according to the existing practice, but on the basis of the increased hourly or daily rates fixed by this award instead of the existing hourly or daily rates. The advances awarded cover and are to be deemed to be in full satisfaction of any claims with respect to the bonus of 12½ per cent. The new rates are payable as from the commencement of the day shift on Monday, May 6. The terms of the award are similar to those of the general award issued by the committee on May 3 for ports other than London; in the absence of representatives of the London employers at the hearing on April 26, the committee are not in possession of detailed information which would enable them to make provision for any special circumstances which may exist. If in the application of the award there are points of difficulty upon which the parties are unable to agree the committee will be prepared to hear the parties thereon and give a decision.

The report of the committee appointed to consider the resettlement of officers has been approved by the Minister of Reconstruction, and in accordance with its recommendations the Minister of Labour is proceeding to set up a department to be known as the "Appointments Department," in order to provide advice and assistance to officers and others requiring professional and business appointments on their return to civil life. The Headquarters Offices of the department will be at Gresham House, Old Broad-street, E.C. 2, and will be under the direction of Mr. Charles Hume McCall. The department will be represented in the provinces by branch offices.

The Professional Business Register of the Ministry of Labour and the Officers' Technical Training Courses of the Ministry of Munitions will be merged in the new department. With it will be associated two committees, one dealing with questions affecting appointments, and the other with questions of training. The former committee will comprise representatives of the principal professional and business organisations, together with representatives of ex-officers and of the Government departments concerned. Local committees similarly composed will be associated with the department's provincial offices. The Training Committee will be an Interdepartmental Committee jointly appointed by the Ministry of Labour and the Educational and other departments interested, including the Board of Agriculture and Ministry of Pensions, and the chairman will be nominated by the Board of Education. It will contain representatives of the universities and other educational organisations, as well as representatives of commerce and industry. With the advice and assistance of these committees the department will endeavour to find suitable appointments of a professional and business character for ex-officers and others requiring them, and either directly, or through the Educational Departments, will also endeavour to arrange facilities for those who wish to undergo courses of instruction either of a general or technical character.

No fees are charged either to the applicants for appointments or to employers. Further information may be obtained from the Ministry of Labour, Appointments Department, Gresham House, Old Broad-street, E.C. 2.

The Amalgamation Committee recommend the following terms of amalgamation with other metal-working unions of the Amalgamated Society of Engineers:—

1. In arranging terms of amalgamation the executive council shall take into consideration the future financial liability of the society to the members of any trade union whose members are often rendered unemployed by weather conditions.

2. Members of other organisations shall be placed in the class according to their qualifications as tradesmen, but those who have joined their trade union over 45 years of age shall be placed in the class for which they are eligible under A.S.E. rules.

3. Any trade union having a financial value per member equal to the A.S.E. who agree to amalgamation shall pay A.S.E. contributions and be entitled to A.S.E. benefits, including superannuation, in accordance with A.S.E. rules. The value of funds per member shall be determined by the value of the funds of the class for which the member is eligible.

4. The members of a trade union where the financial value per member of their union is less than that of the A.S.E. shall pay the A.S.E. scale of contributions, and shall be entitled to the benefits of their original union for twelve months and thereafter to A.S.E. benefits, with the exception of superannuation benefit, the qualifying period for which shall commence from the date of amalgamation unless covered by Clause 5. Members over 40 years of age not qualifying for superannuation benefit shall be exempt from superannuation levy, and the executive council shall determine the amount of weekly contributions they shall pay, taking into consideration their liability to continuous sick or donation benefit.

5. Any trade union whose funds per member are not equal to the funds per member of the A.S.E. may pay 2*l.* per member for those who will come under the superannuation rule to the superannuation reserve fund and be entitled to A.S.E. superannuation benefit, except those members already drawing superannuation benefit, who shall be entitled to the benefit they are in receipt of under the rules of their original trade union. Where the difference in total funds is less than 2*l.* per member such trade union shall only pay the difference necessary to equalise the funds. Members under this section shall qualify for superannuation benefit from the date of last joining their trade union.

6. The full time elected officials of unions shall by mutual arrangement be found positions as councilmen, organisers, secretaries, or district secretaries without election for a period of years up to the third election after amalgamation. Officials preferring not to accept office under this clause may be paid a sum of money as compensation for loss of official employment.

7. Full-time elected officials shall be paid the wages paid them in their original union for the non-elective period, but should it be less than the A.S.E. rate they shall be paid the A.S.E. rate—*i.e.*, 4*l.* 10*s.*, or as per rule.

8. The name of the new organisation shall be determined by the societies agreeing to amalgamate.

9. Subject to the above proposals being ratified by the members, the Executive Council shall convene a conference of the engineering trade unions eligible for amalgamation in a town outside of London—the Executive Council and Amalgamation Committee to represent the A.S.E.

The above terms are given in the ballot paper, and the votes are to reach the general office in London not later than by the first post on June 28.

The United States Bureau of Labour Statistics, in a recent report, states that in the machine manufacturing industry there are still too many casualties, in spite of all that has been done to prevent accidents. The bureau investigated 194 plants and found that on an average each worker lost 5·6 working days out of 300 in a year. Yard labour showed the highest percentage, with 29 days lost per worker in a year owing to accidents. Boiler shops also showed a high rate of lost time owing to accidents, primarily as the result of insecure trestles and scaffolding. The high rate of accidents in yards was due to general neglect of safe location and construction of transportation systems, coupled with a lack of safety precautions. Accidents from falling objects were very frequent, the annual rate being 14 per 1,000 workers. Cranes and hoists appeared to cause the most serious accidents if the average time lost through accidents under this head was considered as a measure of the severity of the injury.

A conference was held at York last Wednesday between the Shipbuilding Employers' Federation and the Shipyard Trade Unions Joint Committee, the object being to improve industrial conditions in the shipyards and accelerating the output of tonnage. The agreement with which the conference dealt had been approved in draft by Lord Pirrie, Controller of Merchant Shipping, and it is to come into operation immediately.

Arrangements are made for avoiding disputes, so that shipbuilding and ship-repairing may be accelerated. The administrative proposals will practically lead to the discontinuance of the Admiralty's Shipyard Control Department. The Admiralty is to be the only central authority to which the shipbuilding or ship-repairing industry will be responsible, and the Admiralty will make its own arrangements as between other Government Departments, with the object of securing co-operation between the industry and the Admiralty. Among the committees to be established are Yard Committees to consider suggestions for increasing output and prepare monthly estimates of work, also to consider hindrances to output, including lost time, and to exercise a supervisory interest in carrying out the schemes of District Joint Committees and the National Joint Committee. The latter committee is to be consulted before the issue of any general orders or instructions by the Admiralty, so that their opinion may first be received in regard to the steps to be taken to secure the fullest output.

The joint proposals having these objects in view were submitted to the Government in November, but the scheme was delayed until the First Lord made his statement in the House of Commons early in March. When Lord Pirrie became Controller of Merchant Shipping the subject was reopened, with the result given above.

HARBOUR CONSTRUCTION AT CHEMULPO.—With regard to the harbour construction at Chemulpo, undertaken by the Government Engineering Bureau a few years ago, the local press, says *The London and China Telegraph*, states that an official concerned in the work has reported that operations have been steadily progressing. The reclamation of the sea front and the construction of locks are all but completed, and the utmost efforts are being put forth for constructing roads. The work is expected to be finished before next September. The construction of railway tracks, as well as the building of warehouses, on the reclaimed ground will also be completed by that time. This means that steamers will be able to berth at the docks about the middle of October. An embankment extending between the port and Wolmi Island was to be started this month, and is expected to be completed in about three years. The total expenditure by the bureau on the work this year is estimated at about 700,000 yen.

RELATIONS BETWEEN PHYSICAL CONSTANTS.—Guye having shown in 1890 that the boiling-point (in absolute degrees) of organic liquids under reduced pressure (10 mm. to 20 mm. of mercury) is half the critical temperature, W. Herz, of Breslau, found, in 1916, that the boiling-point under any pressure is a constant fraction of the critical temperature, and he has since drawn attention to other regular relations, in his contributions to the *Zeitschrift für Anorganische Chemie*. In homologous series the ratio of the absolute boiling-point to the critical temperature increases with the number of carbon atoms. Measuring the viscosity (internal friction) and the specific volume, and expressing the results in absolute measures, he finds that the fluidity (the reciprocal of the internal friction) is proportional to the specific volume in aqueous solutions of many salts (organic and inorganic), acids and bases. For the members of homologous series the product of the expansion coefficient and the boiling-point is approximately constant; the product of the specific heat at 20 deg. C. by the density at the same temperature is also approximately constant for the members of a series. All these regulations would follow from the equation of state, if there were any such generally applicable equation.

REGULATIONS AS TO EMPLOYMENT.

TO THE EDITOR OF ENGINEERING.

SIR,—The many restrictions imposed on the civil population generally and upon engineers in particular have, on the whole, been observed and respected with extreme loyalty, and further demands would doubtless receive a ready response so long as the exigencies of national requirements warranted this. This very fact should, however, invoke discretion in the application and enforcement of regulations which, whilst being apparently advantageous to the unanimity of the national cause, are as a matter of fact obstacles to the attainment of maximum efficiency.

In your advertisements for staff appointments for instance, it is stipulated that applications will be considered only from those within a radius of 10 miles and such applicants shall not be engaged on Government work.

It is common knowledge that in the past these regulations have been honoured more in the breach than in the observance, with the result that an engineer whose qualifications for filling a post demanding a high standard of experience and training has been able to transfer his services from a firm who were not employing him at his maximum efficiency. Many cases can be cited of this nature and undoubtedly the gain to the nation has been increased. It now seems that in the future all this is forbidden, and the strict letter of the Defence of the Realm Act is to be observed; applications have to be censored by the nearest Labour Exchange.

Before forwarding the application to the advertiser the Labour Exchange manager has to be satisfied—

1. That applicant is not employed on Government work, and

2. That applicant's present employers are not engaged on Government work.

What is the use of advertisers stating that an application will be considered confidentially when such application has *per se* to run the gauntlet of the inquisition of the Labour Exchange, with the probability of applicant's employers being notified that he is offering his services to another firm?

Again, how is it possible for an applicant to know from a mere box number whether he is employed within 10 miles or 100 miles of advertiser?

What is, and what is not Government work? If a broad view of the definition of Government work is taken can it be possible that there is a single eligible applicant for a high administrative post, excepting a discharged member of His Majesty's forces (a very remote contingency)? Surely at this date every engineer eligible for such a vacancy and between the ages of, say, 30 and 50, is either engaged directly or indirectly on Government work.

In the writer's opinion the above regulations offer a premium to those firms whose dog-in-the-manger policy precludes an efficient and qualified applicant from being employed at his most efficient "load factor." The removal of similar restrictions on the workmen have not resulted in the wild stampede so falsely predicted, and the national interests would be best served by allowing the appointment by open selection of those candidates whose qualifications befit them for posts of greater scope and usefulness in advancing the national cause.

Under existing conditions it is open to an employer to terminate an engagement with the possibility of the military authorities putting the employee into the Army before he has the opportunity of obtaining another berth, whilst at the same time another post is remaining unoccupied for want of just such a man. It is neither equitable nor is it conducive to the national interest, and justice and efficiency call for the removal of the embargo.

Yours faithfully,

May 14, 1918. "EFFICIENCY."

AIR STANDARD INTERNAL COMBUSTION ENGINE CYCLES.

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of March 29 giving the report of the meeting of the Physical Society of London on March 8, I read the inquiry of Dr. H. S. Allen asking if it were not possible suitably to choose the exhaust curve $\phi(p\,v) = 0$ of an air standard internal combustion engine, with the object that the cycle bounded by $\phi(p\,v) = 0$, the two adiabatic curves $p\,v^\gamma = a$, $p\,v^\gamma = b$ and the combustion curve $f(p\,v) = 0$ (supposed known) should have the efficiency $\eta = 1 - \left(\frac{1}{r}\right)^{\gamma-1}$, r being the compression ratio and γ the ratio of the two specific heats of air.

Below I give a solution of this problem which gives a very simple expression and an easy graphical determination for $\phi(p\,v) = 0$:—

Let us call W the work of the cycle, Q the heat expended in the cycle, A the reciprocal of Joule's equivalent.

In general efficiency η is a function of $a, b, \gamma, f(p\,v) = 0$ and $\phi(p\,v) = 0$. But here:

$$\eta = \left[1 - \left(\frac{1}{r}\right)^{\gamma-1}\right] = \frac{A\,W}{Q} = 1 - \left(\frac{V_0}{V_1}\right)^{\gamma-1}$$

where V_0 and V_1 are, on substituting for p in terms of V, given by $f(a\,V_0^{-\gamma}, V_0) = 0$ and $\phi(a\,V_1^{-\gamma}, V_1) = 0$. That is to say

$$\frac{\delta\,\eta}{\delta\,b} = 0 = \frac{A}{Q^2}\left(Q\frac{\delta\,W}{\delta\,b} - W\frac{\delta\,Q}{\delta\,b}\right) = 0$$

$$\frac{\delta\,W}{\delta\,b} : \frac{\delta\,Q}{\delta\,b} = \frac{W}{Q} = \frac{\eta}{A} = \frac{1}{A}\left[1 - \left(\frac{V_0}{V_1}\right)^{\gamma-1}\right]$$

We have to solve the equation:

$$\frac{\delta\,W}{\delta\,b} = \frac{\delta\,Q}{\delta\,b}\frac{1}{A}\left[1 - \left(\frac{V_0}{V_1}\right)^{\gamma-1}\right] \quad . \quad . \quad (1)$$

Let us write more simply $p\,v^\gamma = u$ and take as independent variables u and v we have

$$\frac{d\,p}{p} + \gamma\frac{d\,v}{v} = \frac{d\,u}{u} \text{ and } p = u\,v^{-\gamma}.$$

The heat Q expended in the cycle is all added along the line A B in the annexed diagram. Whenever heat is added to a body we have the general relation:

Heat added = change of internal energy + external work done.

If then we assume, as it is generally done in the study of the internal combustion engine, that the gas burned follows the laws of a perfect gas, we get—

$$Q = \int_{A\,B}\frac{1}{c_v\,R}(v\,d\,p + \gamma\,P\,d\,v) = \int_a^b \frac{1}{c_v\,R}v\,p\,.\left(\frac{d\,p}{p} + \gamma\frac{d\,v}{v}\right)$$

$$= \frac{1}{c_v\,R}\int_a^b v^{1-\gamma}\,d\,u$$

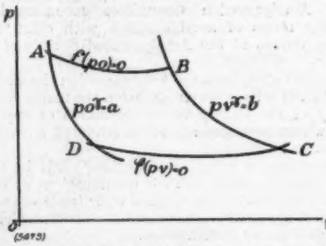
where

c_v = specific heat at constant volume.
R = constant of perfect gas.

Then on replacing u by b we get

$$\frac{\delta\,Q}{\delta\,b} = \frac{1}{c_v\,R}V^{-\gamma+1} \quad . \quad . \quad . \quad (2)$$

where V is given by $f(a\,V^{-\gamma}, V) = 0$.



In the same way we have

$$W = \iint_{A\,B\,C\,D} dp\,dv = \iint d\,v\,d\,u\left(\frac{d\,p}{d\,u}\frac{\delta\,v}{\delta\,v} - \frac{\delta\,p}{\delta\,v}\frac{\delta\,v}{\delta\,u}\right) = \iint v^{-\gamma}\,d\,v\,a\,u,$$

or

$$W = \int_a^b\left(\frac{V^{1-\gamma}}{1-\gamma} - \frac{v^{1-\gamma}}{1-\gamma}\right)d\,u;$$

and

$$\frac{d\,W}{d\,b} = \left(V^{1-\gamma} - v^{1-\gamma}\right)\frac{1}{1-\gamma} \quad . \quad . \quad (3)$$

where V is given by $f(a\,V^{-\gamma}, V) = 0$ and v by $\phi(a\,v^{-\gamma}\,v) = 0$.

Then replacing in (1) the expressions given by (2) and (3) we have:

$$\frac{1}{1-\gamma}\left(V^{1-\gamma} - v^{1-\gamma}\right) = \frac{1}{c_v\,R}V^{1-\gamma}\frac{1}{A}\left[1 - \left(\frac{V_0}{V_1}\right)^{\gamma-1}\right]$$

or

$$v^{1-\gamma} = \left\{\frac{-1+\gamma}{A\,c_v\,R}\left[1 - \left(\frac{V_0}{V_1}\right)^{\gamma-1}\right] + 1\right\}V^{1-\gamma}$$

$$= k^{-1+\gamma}V^{1-\gamma}$$

where

$$k^{-1+\gamma} = 1 + \frac{\gamma-1}{A\,R\,C_v}\left[1 - \left(\frac{V_0}{V_1}\right)^{\gamma-1}\right] \quad . \quad (4)$$

Then

$$V = k\,v \text{ and } P = a\,V^{-\gamma} = a\,k^{-\gamma}\,v^{-\gamma} = p\,k^{-\gamma},$$

v and p being a solution of $f(k\,v, p\,k^{-\gamma}) = 0$ and $\phi(p\,v) = 0$, we may write

$$\phi(p\,v) = f(k\,v, k^{-\gamma}p) = 0.$$

This is the expression of the exhaust curve, which, it will be seen, can be deduced from the combustion curve by changing p in $k^{-\gamma}\,p$ and v in $k\,v$, k being a constant given by (4).

It is thus very easy to deduce a graphical construction for the exhaust curve, although we do not know the equation of the combustion curve, since this latter has been determined only experimentally.

I am, Sir, yours faithfully,

From the Front, April 17, 1918. V. CHIARA.

TRADING WITH THE ENEMY ACT.—The Controller of the Foreign Trade Department has sent us a copy of a new Consolidating List (No. 51A) containing the names of over 3,500 persons and firms with whom persons in the United Kingdom are forbidden to trade under the Trading with the Enemy (Statutory List) Proclamation. It is important that every one engaged in foreign trade should realise that he is under an obligation to make himself familiar with the Statutory List and to observe it in his dealings. Copies of the Consolidated List and of all additional lists may be obtained at a small cost from the Superintendent of Publications, His Majesty's Stationery Office, Imperial House, Kingsway, W.C.

THE OPTICAL SOCIETY.

AT the monthly meeting of the Optical Society held at the Imperial College of Science on May 9, a paper was presented by Naval Instructor T. Y. Baker, R.N., and Major L. N. G. Filon, D.Sc., F.R.S., Royal Air Force, on "Spherical Aberration." The authors had considered the subject from the point of view of an optical design for a system of coaxial thin lenses (separated by air) in which the focal lengths and separations of lenses are determined from general consideration of the functions that the instrument has to perform, and from the necessity of correcting for colour. A design carried out in this manner leaves available for the correction of spherical aberration the forms of the various lenses. For a thin lens of definite focal length made of a definite variety of glass the difference of curvature of the two faces of the lens is fixed, but the mean of these two curvatures is arbitrary. When the first order aberrations alone are considered the caustic of the emergent rays is a semi-cubical parabola with an equation $27\,a\,y^2 = 4\,x^3$. The parameter a of the caustic was shown to be obtainable from the formula:

$$a = \frac{f(1-M)^4}{2\,n\,(n+2)}\left[\left\{C\,f\,(n+2) - (n+1)\left(\frac{1+M}{1-M}\right)\right\}^2 - \frac{n^2}{4}\left(\frac{1+M}{1-M}\right)^2 - \frac{n^3\,(n+2)}{4\,(n-1)}2\right],$$

in which f is the focal length of the lens, C the mean curvature of the faces, M the linear magnification of the image and n the refractive index of the glass.

Put in this form it is clear that the parameter of the caustic is least given image position when $C\,f = \frac{n+1}{n+2}\frac{1+M}{1-M}$, and that there is therefore a theoretically best shape to give the lens for any particular image position. When the image position approaches the lens this best shape becomes a steep meniscus and the lens is impossible from a manufacturing standpoint. The authors tentatively suggested three as a numerical value which $C\,f$ must not exceed.

Over-correction of a lens is only possible if the quantity inside the square bracket is negative, a result which is found if (1) the shape term can be made zero and (2) if the image position lies between two points, dependent upon the refractive index, which are situated, if n equals 1·50 at 0·39 f beyond the lens and 0·63 f in front, and if $n = 1·70$ at 0·44 f beyond the lens and 0·83 in front. These ranges are, however, approximately those for which the steel meniscus forms are required, and consequently over-correction is impossible except for a minute amount in the neighbourhood of 0·7 f in front of the lens, when a very dense glass is used. The general conclusion of the authors was that all lenses are necessarily under-corrected in themselves for all image positions.

With a series of lenses along an axis a method of determining the parameter of the final caustic was shown and numerical examples given for a Ramsden eyepiece and a four-lens erecting eyepiece. It was also proved that spherical aberration of the first order cannot be removed from the system if the lenses are all positive or all negative.

When aberrations of the second order have to be included the semi-cubical parabola is no longer a sufficiently close approximation to the caustic, which, in general, develops two new cusps off the axis. The general appearance of such a caustic was examined as well as the possibility of deriving the two parameters from trigonometrically calculated rays.

The authors urged that the full import of the higher order aberrations could best be understood by an actual construction of the caustic in the several media, from which the trained optical calculator would be able to tell from the shapes of the successive curves how the aberrations of different orders would affect the final image formation and also to form an idea as to which lenses were having most serious effect, and how changes in the forms of the lenses would enable him to diminish the spherical aberration of the final image. An interesting similarity was shown between the second order caustic and the curves of pro-metacentres that are drawn by naval architects.

NEW ORE FLOTATION MACHINE.—Some of the flotation machines which mix the ore pulp with oil and air are provided with beating appliances which require considerable power for their working. The machine of F. O. Groch and W. E. Simpson, described in the Bulletin of the Canadian Mining Institute, of March, 1918, is said to be very economical in power consumption. The machine consists of a centrifugal impeller which is sub-divided horizontally by a metallic disc so as to operate after the manner of a pair of centrifugal pumps. A vertical pipe, through which oil spray and air are fed downward, widens out into a doubly-conical chamber, in which the disc mentioned is revolving, the chamber wall being slotted in the plane of the disc. Below this chamber the pipe narrows again, and this lower end dips into the outer pulp vat. The suction of the pump draws the pulp up into the lower chamber; in the upper chamber the mixture of atomised oil and air descends, and the pulp and oil particles are thrown out through the peripheral slot in the chamber and rise in the inner vat, which surrounds the pipe at some distance; the light particles continue to float, whilst the heavier particles sink in the outer vat. A vacuum of 2.75 in. of mercury is said to be produced at 450 revolutions per minute, and a vacuum of 6 in. at 750 revolutions. A standard machine fitted with six impellers for a capacity of 55 tons of ore per day requires 7.5 horse-power. The machines are in successful use in the Cobalt district of Ontario for dealing with silver and molybdenite ores.

NOTE ON INCLUSIONS IN STEEL AND FERRITE LINES.

By DR. J. E. STEAD, F.R.S., Vice-President.

THE object of this note is to place on record a large number of experiments to determine whether or not non-metallic inclusions in steel induce ferrite to crystallise round them. Although the author had advanced much evidence to show that ferrite lines in steel plates, forgings &c., are rather high in phosphorus, and although inclusions might be embedded in the white ferrite, they were incidental occurrences and not the cause of the segregation of the ferrite.

It was M. Ziegler† who first suggested that the cause of segregation was the inclusions, and other authorities have accepted that view and have advanced evidence in support.

As, however, opinion is divided it seemed advisable to dismiss preconceived conclusions and to start *de novo* to settle the question once for all.

On reconsideration of the question, the following problems presented themselves, viz. :—

Problem I.—If a variety of different inclusions were made in steel mechanically, would ferrite crystallise round any of them after heating and cooling the metal ?

Problem II.—If hermetically sealed, mechanically-produced cavities were made in steel, would the ferrite or cementite crystallise on the walls of these ?

Problem III.—If the phosphorus, usually associated with ferrite streaks and non-metallic inclusions, could be removed or diffused out of such association, would the inclusions left behind lead ferrite to form envelopes round them ?

Problem IV.—Would pure slag inclusions—sometimes naturally present in steel—effect a segregation of the ferrite ?

PROBLEM I.

Will ferrite crystallise round mechanically-made inclusions ?

In an endeavour to answer this question, a series of bar steels containing respectively 0·16 per cent., 0·34 per cent. and 0·48 per cent. of carbon were selected. A series of holes, about 1 in. in depth and ¼ in. in diameter, was drilled in each. Powdered substances, a list of which is given below, were put into these holes, and, after compression, they were closed by steel plugs which were hammered into place and afterwards melted in by an electric arc.

List of Substances Used.

1. Crushed transparent quartz crystal.
2. Calcined magnesia.
3. Fluorspar.
4. Lime.
5. Basic slag from an open-hearth furnace.
6. Crystals of cyano-nitride of titanium.
7. Acid slag from an acid open-hearth furnace.
8. Mill-scale.
9. Manganese sulphide, obtained from a blast-furnace bear.

After filling and sealing the cavities some of the bars were placed inside a 3-ton mass of molten blast-furnace slag and were allowed to cool down with the slag. Others were heated to about 1,200 deg. C. in a forge furnace and allowed to cool in the furnace.

Those heated in the slag were cut into two parts. One part of each was forged down to a flat plate and reheated to above 1,000 deg. C. in a mill furnace, and allowed to cool down with the furnace. They were all, after treatment, sectioned, polished and etched, and examined under the microscope, and a record of the structures taken.

It is not necessary to describe every trial in detail ; it is sufficient to state the results in general terms.

In no case did quartz, magnesia, lime, basic open-hearth slag, cyano-nitride of titanium, or manganese sulphide inclusions, attract or lead to the development of a ferrite layer. Strange to say the exception was fluorspar, but this was only in the case of the steels containing 0·16 per cent. and 0·34 per cent. carbon, which had been heated and cooled in molten slag.

As fluorspar is never present naturally as an inclusion in steel, although the question as to why ferrite should crystallise out round it, is of scientific interest, it is outside the question at issue.

The oxides of iron present to the extent of about 20 per cent. in the basic and acid slags partially decarburised the steel, but in no case did continuous envelopes of ferrite appear round these inclusions. The mill-scale inclusions decarburised an envelope of the steel as was to be expected. The thick ferrite envelope formed was due to removal of the carbon, and not to any attraction of the inclusion. Coincidentally the mill-scale was partially reduced to the metallic state. Greatly reduced micrographs of many of the sections are given below.

PROBLEM II.

Will ferrite or cementite crystallise on the walls of hermetically-sealed, mechanically-produced cavities ?

To answer this question, cavities were made in steels containing 0·45 per cent. and 1·50 per cent. carbon respectively, and after hermetically sealing them, the bars were heated and cooled in molten slag. They were sectioned and examined, but no ferrite layers were found on the walls of the steel containing 0·45 per cent. carbon, or cementite layers on the walls of the steel containing 1·50 per cent.

The crystalline structure was very coarse in each and the grains exceedingly large. Had there been no cavities before treatment, and if holes had been drilled after treatment into the solid steel and sections made and compared with those cut through the other cavities, no difference could have been detected.

PROBLEM III.

If phosphorus could be removed from association with the ferrite and non-metallic inclusions, would the inclusions left behind lead ferrite to form envelopes round them ?

It has been shown in a separated paper on "Iron, Carbon and Phosphorus," that when phosphorus and iron are irregularly distributed in iron or soft steel, if these metals are heated to 1,200 deg. C. and above for a sufficient length of time, the phosphide becomes uniformly distributed. If a forged steel, low in carbon, contains white streaks of ferrite which enclose non-metallic inclusions, and if these lines are due to phosphorus and not to non-metallic substances, then by causing the phosphorus to diffuse into the surrounding metal, there will be no ferrite streaks or ghost lines round the inclusions on cooling. The evidence which follows indicates that phosphorus can be made to leave the inclusions, and that when this occurs ferrite lines disappear.

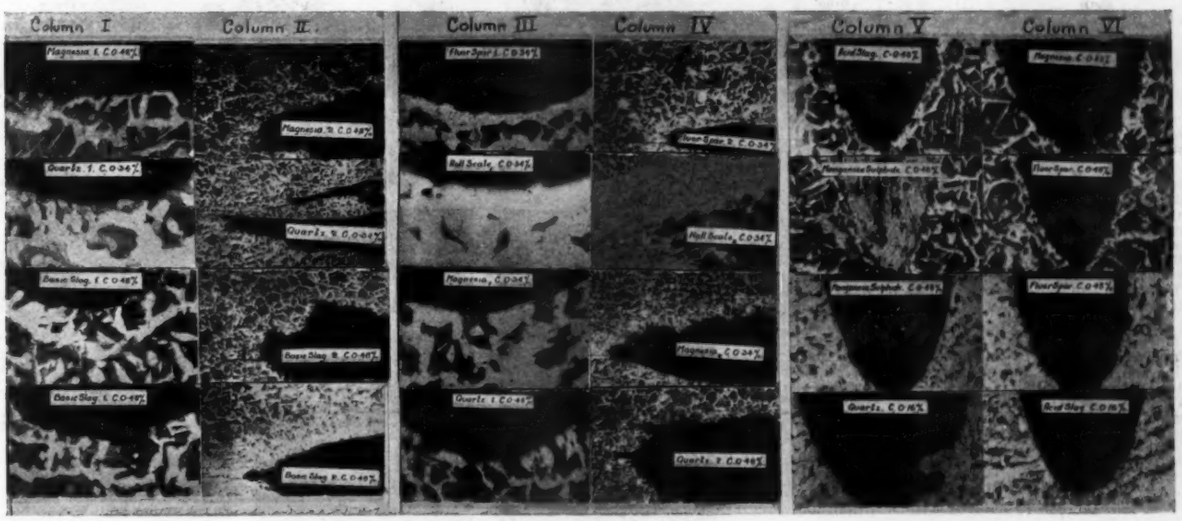
The photographs overleaf are of two forged steels identical in all respects, excepting that A contained about 0·07 per cent. phosphorus and B about 0·3 per cent. phosphorus. The silico-sulphide inclusions were equal in each, and, in both, although not visible in the photographs, they are located in the white ferrite.

The steels were in the forged condition. The white ferrite bands or lines are in thickness and mass roughly proportional to the phosphorus. These forged steels were heated and cooled in molten slag at about 1,200 deg. C., and photographs C and D indicate the complete absence of ferrite in bands. The inclusions remained and were located indiscriminately in both pearlite and ferrite.

It has been found in the case of ship plates, which usually have a zebra-like structure in etched cross-sections that if the plates are heated to 1,000 deg. C. and slowly cooled, the ferrite bands reappear. Cupric reagents prove that the phosphorus is still concentrated in these lines. When, however, the plates are heated for a long time at 1,200 deg. C. the phosphorus becomes inter-diffused and after slow cooling no ferrite bands appear, but the inclusions still remain in the original position. Mr. Whiteley has fully confirmed this observation.

Long ago the author made a compact mass of soft steel by piling bars one on top of another, and causing them to unite by placing powdered iron phosphide between adjacent bars and heating to above 1,000 deg. C. for a few minutes. There was a little slag matter in the phosphide, and this constituted minute non-metallic inclusions. After forging down the pile to a plate and sectioning, the polished and etched surface consisted of white lines enclosing the inclusions, and these were sandwiched between thicker layers of steel containing pearlite in patches.

After heating and cooling in molten slag there were no longer any white lines, and the pearlite and ferrite were equally distributed, yet the trains of inclusions remained in the original position. He had drawn attention in a previous paper to the fact that in certain cemented Swedish bars the non-metallic inclusions were associated with ferrite and pearlite indiscriminately.



PROBLEM IV.

Will pure slag inclusions effect a segregation of ferrite ?

As a rule non-metallic inclusions consist of mixtures of sulphides and silicates and are usually associated with ferrite surrounding them, which is richer in phosphorus than the metal external to them.

It occasionally happens, however, that in small castings particles of pure silicate slag are mechanically trapped in the steel. It was for these that a search was made, and eventually two cases were found in which inclusions of the character mentioned were discovered, but they were not surrounded by envelopes of ferrite ; indeed, pearlite and ferrite abutted against the sides of the slag. The cupric reagent proved that the slag was not associated with metal rich in phosphorus.

This evidence is quite in conformity with all the other evidence, and shows that if inclusions, such as are met with in steel, are not associated with phosphorus, no ferrite appears round them in continuous envelopes.

An illustration proving that phosphorus is associated with normal inclusions in ferrite ghost specks in steel castings is given in Figs. S, E, F and G, page 560. The three photographs were taken from the same area in a portion of the same steel as that in the last condition:—

E—was etched with a dilute solution of nitric acid in alcohol, and only the inclusions, ferrite and pearlite appear. F—was etched with Stead's cupric reagent, which has stained the metal surrounding the inclusion, but has left unstained the parts rich in phosphorus. G—was etched with a dilute aqueous solution of picric acid, which attacked the parts of ferrite where the phosphorus was most concentrated.

On comparing E and F it will be seen that while the copper reagent indicates where the phosphorus exists, the picric solution locates the parts in which it is most concentrated. On heating the steel for 5 hours at 1,200 deg. C. the phosphorus diffused out of the ghosts, leaving the inclusions behind no longer enveloped by ferrite.

FINAL CONCLUSION.

The evidence appears to be conclusive that non-metallic inclusions and empty cavities in steel do not lead ferrite to crystallise round them, and that it is the phosphorus—almost always associated with the inclusions

* Paper read before the Iron and Steel Institute on May 3, 1918.

† "Sur la Crystallisation du Fer alpha," *Revue de Métallurgie*, vol. viii, September, 1911.

—which leads to the formation of ferrite ghost lines. When the inclusions are not associated with high phosphorus no ferrite envelopes appear.

THE JURASSIC IRONSTONES.*

The Jurassic Ironstones of the United Kingdom—Economically Considered.

By F. H. HATCH, Past-President of the Institution of Mining and Metallurgy.

(*Continued from page 517.*)

Chemical Composition.—The average composition of the Middle Lias ironstone of South Lincolnshire and Leicestershire has been calculated from 23 analyses supplied by blast-furnace firms. The following localities are represented: Caythorpe and Honington (5 samples), Harston (2), Easton (6), Eastwell (7), Waltham (3). The method of calculation is the same as that already described in dealing with the Northampton ironstone. The results are as follow:—

No. of Analyses Used in the Calculations.	—	Calculated Average. As Received.	Dry.
23	Fe	25·24	30·19
15	Mn	0·23	0·27
23	SiO_2	10·87	13·00
20	Al_2O_3	8·00	9·57
23	CaO	9·55	11·42
16	MgO	0·57	0·68
22	S	0·11	0·13
22	P	0·25	0·30
23	Moisture	16·40	—
	Difference = Combined water, CO_2 and O	28·78	34·44
		100·00	100·00

The range of the percentages of the different constituents in the analyses used is as follows:—

	Per Cent.		Per Cent.
Iron	from	29·80 to	17·13
Manganese	„	0·34 „	0·15
Silica	„	17·00 „	7·08
Alumina	„	10·69 „	5·28
Lime	„	23·90 „	1·36
Magnesia	„	0·86 „	0·28
Sulphur	„	0·20 „	0·04
Phosphorus	„	0·42 „	0·14
Moisture	„	27·00 „	9·90

The average composition of the Middle Lias ironstone of Oxfordshire (including Byfield) has been calculated from analyses supplied by blast-furnace firms. The following quarries are represented: Adderbury (2 analyses), Astrop (1), Milton (8), Byfield (26), Brymbo—Park Farm (average of 11 trains), and Brymbo—Redlands (average of 14 trains). The usual method of calculation has been followed. The results are as below:—

—	Calculated Average. As Received.	Dry.
Fe	23·97	28·32
Mn	0·27	0·32
SiO_2	10·16	12·04
Al_2O_3	7·55	8·94
CaO	12·18	14·43
MgO	0·57	0·67
S	0·06	0·07
P	0·23	0·27
Moisture	16·60	—
Combined H_2O, CO_2, and O by difference	29·41	34·94
	100·00	100·00

The range of the percentages of the different constituents in the analyses used is as follows:—

	Per Cent.		Per Cent.
Iron	...	30·45 to	17·72
Manganese	„	0·64 „	0·09
Silica	„	21·59 „	6·89
Alumina	„	9·70 „	3·86
Lime	„	24·23 „	2·26
Magnesia	„	1·61 „	0·02
Sulphur	„	0·16 „	0·01
Phosphorus	„	0·31 „	0·13
Moisture	„	25·68 „	4·46

The great variation in the proportion of silica and lime in the above analyses of Marlstone is due to the fact that while in some cases the stone has remained unchanged, the lime and most of the iron being present in the form of carbonate, in others it shows evidence of complete reconstruction, for the lime has been dissolved and removed, while the iron has been oxidised and hydrated. Whether, in any given case, this takes place or not, depends on the thickness and permeability of the cover. When this is pervious the surface waters effect the oxidation and hydration of the ironstone and, by removing the lime, raise the percentage of the iron and also of the silica. Speaking generally, the Marlstone is a limey ironstone, but under the conditions just described it may be distinctly siliceous.

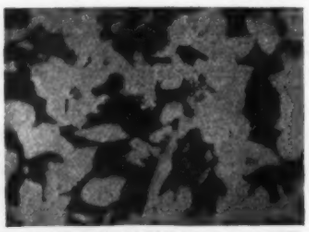
* Paper read before the Iron and Steel Institute on Thursday, May 2, 1918. Published by permission of the Controller of Iron and Steel Production, Ministry of Munitions.

INCLUSIONS IN STEEL AND FERRITE LINES.

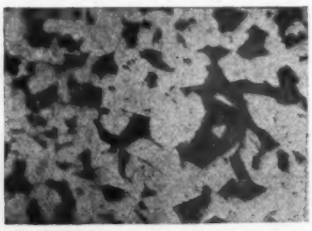
(*For Description, see previous Page.*)

A.—Forged Steel, containing 0·07% P. × 50.

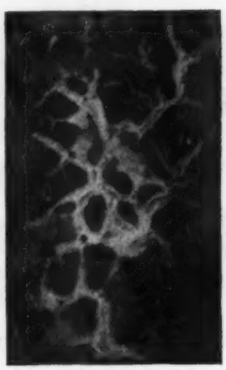
B.—Forged Steel, containing 0·3% P. × 50.



C.—Same as A, after heating to about 1,200° C. × 50.



D.—Same as B, after heating to about 1,200° C. × 50.



E.—Etched with nitric acid. × 50.

F.—Etched with cupric reagent.

G.—Etched with aqueous picric acid.

No. of Analysis.	Name of Quarry.	Situation.	Owners.	Source of Information.
1	Astrop	Near Banbury, Oxfordshire	Alfred Hickman	Alfred Hickman.
2	Harston	N. of Melton Mowbray, Leicestershire	Stanton Ironstone Company	Shelton Iron, Steel and Coal Company.
3	Caythorpe	S. Lincolnshire	Walter Burke	Midland Coal, Coke and Iron Company.
4	Eaton	N. of Melton Mowbray, Leicestershire	Holwell Iron Company	Holwell Iron Company.
5	Harston	„ „ „	Stanton Ironstone Company	Midland Coal, Coke and Iron Company.
6	Redlands	Near Hook Norton, Oxfordshire	Brymbo Steel Company, Limited	Brymbo Steel Company, Limited.
7	Adderbury	Near Banbury, Oxfordshire	Cochrane and Co.	Cochrane and Co.
8	Eaton	N. of Melton Mowbray, Leicestershire	Holwell Iron Company	Park Gate Iron and Steel Company.
9	Eaton	„ „ „	„ „	Holwell Iron Company.
10	Adderbury	Near Banbury, Oxfordshire	Cochrane and Co.	Cochrane and Co.
11	Park Farm	Near Hook Norton, Oxfordshire	Brymbo Steel Company, Limited	Brymbo Steel Company, Limited.

By averaging the siliceous and limey analyses separately, the following results are obtained:—

	Siliceous Ironstone.	Limey Ironstone.
Fe	27·91	22·43
Mn	0·28	0·24
SiO_2	13·28	9·39
Al_2O_3	8·03	7·36
CaO	3·79	14·89
MgO	0·42	0·61
S	0·05	0·06
P	0·22	0·23
Moisture	20·56	13·85
Difference = Combined water, CO_2 and O	25·46	30·94
	100·00	100·00

On the next page are selected analyses of Middle Lias ironstone in the South Lincolnshire, Leicestershire and Oxfordshire districts as received at the ironworks. The additional figures (columns 6A and 11A) in the case of the Redlands and Park Farm ironstone represent the averages of 11 and 14 train loads respectively.

THE CLEVELAND IRONSTONE.

The ironstone bed which is the source of the bulk of the well-known Cleveland iron, is known as the Main Seam. Its relative position in regard to the other iron-bearing seams of the district is shown in the table on the next page.*

In addition to the Main Seam, some of the other seams have been worked to a small extent at different times. Thus the Top Seam was worked some fifty years ago at Rosedale, south of the Esk Valley. It carried small patches of magnetic ore. Ore is still being won

* See also "The Geology of North Cleveland," by George Barrow, *Mem. Geol. Survey*, 1889, and Proceedings of the Cleveland Institution of Engineers, 1877–1880, pages 108, 180.

ANALYSES OF IRONSTONE AS RECEIVED. SOUTH LINCOLNSHIRE, LEICESTERSHIRE AND OXFORDSHIRE.

	1. Astrop.	2. Harston.	3. Caythorpe.	4. Eaton.	5. Harston.	6. Redlands.	6A. Redlands.
Fe	21·29	24·00	24·37	24·67	25·90	27·40	25·53
Mn	0·12	0·20	0·27	0·29	0·30	0·38	—
SiO_2	7·09	9·92	10·67	10·25	8·77	8·84	9·69
Al_2O_3	7·45	8·80	6·71	6·93	9·05	9·28	—
CaO	15·65	9·44	12·74	10·05	11·07	12·37	11·23
MgO	0·92	0·48	0·83	0·68	0·39	0·64	—
S	0·06	0·20	0·04	0·05	0·13	0·06	—
P	0·31	0·14	0·16	0·29	0·22	0·15	—
Moisture	14·50	20·00	13·90	17·00	14·80	11·60	13·90
O	8·58	9·56	10·62	11·06	11·46	11·90	—
Combined H_2O and CO_2	23·09	—	19·63	—	17·89	—	—
Other constituents	0·20	—	—	—	—	—	—
Loss on ignition	—	17·17	—	19·50	—	17·15	18·42
Total	99·86	99·91	99·94	100·77	99·98	99·77	—
Fe in sample dried at 212 deg.	24·90	30·00	28·30	29·73	30·40	31·00	29·65
Character of stone	Limey	Siliceous	Siliceous	Siliceous	Almost self-fluxing	Self-fluxing	

	7. Adderbury.	8. Eaton.	9. Eaton.	10. Adderbury.	11. Park Farm.	11A. Park Farm.
Fe	27·13	27·69	29·80	30·13	31·20	29·89
Mn	0·09	—	0·30	0·20	0·33	—
SiO_2	9·27	14·00	11·05	9·89	10·45	12·64
Al_2O_3	5·29	6·41	9·60	7·04	9·18	—
CaO	11·68	6·80	2·97	3·89	2·34	2·07
Mgo	0·08	—	0·63	0·30	0·33	—
S	0·09	0·04	0·05	0·03	0·04	—
P	0·27	0·38	0·33	0·27	0·13	—
Other constituents	1·59	—	—	1·30	—	—
Moisture	12·20	14·00	19·00	19·00	22·00	19·53
O	12·16	11·86	13·30	13·58	13·65	—
Difference	20·15	—	—	14·37	—	—
Loss on ignition	—	18·06	12·07	—	10·21	12·85
Total	100·00	99·24	100·00	100·00	99·86	—
Fe in sample dried at 212 deg.	30·90	32·20	36·80	37·20	40·00	37·14
Character of stone	Self-fluxing	Siliceous	Siliceous	Siliceous	Siliceous	

from pillars in the East Rosedale mine, the output being about 2,000 tons per week. Small areas of the Top Seam are also worked at Eston and Upleatham. Some work was done on this bed in 1910 by Sir B. Samuelson and Co., at Swainby and Coldmoor on Whorlton Moor, an outlier of the Cleveland Hills, 8 miles to 10 miles north-east of Northallerton. At Swainby the total thickness of the bed reaches a maximum of 20 ft., the best portion being a seam 7 ft. to 9 ft. in thickness and containing on the average 16 per cent. of iron, 16 per cent. of insoluble matter and 22 per cent. of lime. At Coldmoor, the best part of the bed is from 6 ft. to 9 ft. in thickness and contains on the average 16 per cent. of iron, 12 per cent. of insoluble matter and 24 per cent. of lime. As this material would have to be got by mining, its use is at present not a practical proposition. When the bed crops at the surface, the usual processes of oxidation and hydration, accompanied by a leaching-out of the lime, have had the effect of raising the percentage of iron considerably. An analysis of oxidised stone disclosed in one case an iron-content of 38 per cent.

Geological Formation.	Name of Seam.	Thickness of Seams.	Thickness of intervening Strata.
		ft.	ft.
Inferior Oolite	Top of Oolite Seam (horizon of the Northampton Stone)	4 to 9	—
Upper Lias	Strata	—	260
Middle Lias	Main Seam	5½ to 12	—
	Shale	—	2 to 6
	Pecten Seam	1½ to 6	—
	Shale	—	3 to 7
	Two-foot Seam	1½ to 2½	—
	Shale	—	20 to 30
	Avicular Seam	0 to 3	—

The seams underlying the Main Seam have not been separately worked, except at Grosmont in the Esk Valley, where the Pecten Seam has been mined to some extent. The Skinningrove Company has recently started some experimental work on the same seam in the Brotton mine, and this will probably decide the question whether the ore in these thin underlying seams can be won at a profit. The Two-Foot and Avicular Seams are probably too thin and poor to be worked under present conditions; but thirty-five years ago the Avicular Seam was mined over a considerable area at Grosmont and blast furnaces were run on the ore for some years. Mr. H. E. Wright, who in 1912 investigated this seam in the Eskdale mine at Grosmont for Sir Arthur Dorman, informs me that the ironstone averages about 3 ft. in thickness and contains (as mined) 25 per cent. of iron, 16 per cent. of silica and 9 per cent. of lime.

The Main Seam shows at surface on the northern escarpment of the hill on which Eston Beacon stands and around Upleatham Hill and Hob Hill. The outliers formed by the two last-named hills are isolated by the Skelton Beck, which flows in a deep ravine to the sea at Saltburn. The ironstone can be traced on the east side of the ravine to Huntcliff, and thence along or near the coast as far as Staithes. At Old Nab, east of Staithes, it runs out to sea; but a few miles farther east it touches the coast again at Kettle Ness.

The general dip is to the south-east at a low angle (2 deg. to 4 deg.).

At a distance of 1 mile to 1¼ miles south-east of the outcrop at Eston Hill the ironstone bed is cut off by a great strike fault—the Upsall fault. On the south side of this, the ironstone lies relatively higher than on the north side and the "throw" is considerable; but for 2 miles or more across the valley of Guisborough, the ironstone bed has been removed by denudation, the outcrop first reappearing along the escarpment of the main plateau of the Cleveland Hills at Roseberry Topping, Hutton Longcross, Belmont and Sparwood, where it occurs at from 400 ft. to 600 ft. above sea-level.

The ironstone was originally won to some extent in open-cast workings, as at Eston, Upleatham and Hob Hill, but is now all got by mining. It is brought to the surface through adits, as at Eston, Upleatham, Loftus, Boulby and Grinkle Park; or by means of shallow shafts as at Skelton (depth of shaft, 120 ft.), Stanghow (126 ft.), South Skelton (212 ft.), Brotton (281 ft.), and Longacres (286 ft.); or, again, by deeper shafts, as at Liverton (480 ft.), Lumpsey (563 ft.), Skelton (589 ft.) and Lingdale (628 ft.).

The outcrop south of the Upsall fault is also worked by adits at Ayton, Ayton Bank, Roseberry, Belmont and Spawood.

The best part of the Main Seam is in the north-western part of the field. At Eston, Upleatham, Longacres, Lumpsey, Skelton and Park Pit, the ironstone bed is from 9 ft. to 12 ft. in thickness, with an average iron-content of from 28 per cent. to 29 per cent. in the ironstone as mined.

The following section taken in the Lumpsey mine is typical :—*

	Ft.	In.	
Shales		—	
Dogger	1	6	
Sulphur band	0	2	
Top block ironstone	4	6	Total ironstone, 9 ft. 6 in.
Dogger	2	0	
Bottom block ironstone	3	0	
Black hard shale	6	0	
Pecten band		—	

In the direction of the dip, the ironstone becomes less in thickness and split into two parts by a shale band (represented by the second Dogger in the above section), which increases as the ironstone diminishes. In addition the latter becomes leaner, *i.e.*, lower in iron and higher in silica, with the final result that it cannot be worked at a profit. Thus at Stanghow and Lingdale, which are on the dip of Park Pit and Longacres, the average thickness of the ironstone, after deducting the shale band, is from 4½ ft. to 5 ft., the average iron-content being about 26 per cent. At Boulby and Grinkle Park, at the eastern end of the field, it is from 5½ ft. to 6 ft. in thickness, including 1 ft. 6 in. of shale. On the southern line of outcrop at Spawood the ironstone averages 6 ft. 10 in., of which 14 in. is shale, and carries 27 per cent. of iron after 15 per cent. of shale has been picked out. At Belmont, Roseberry, Ayton and Ayton Bank it is from 5½ ft. to 6 ft. in thickness, including about 2 ft. of shale.

The point is even better illustrated by a comparison of sections through the Main Seam taken at different points on the line of dip through the Spawood mine.*

These show a progressive variation in the thickness of the bed from 7½ ft. without any shale to 6½ ft. inclusive of 18 in. of shale—a diminution in the thickness of the ironstone amounting to 35 per cent. within a distance of 2 miles. The change is accompanied by an increasing leanness of the ironstone. Two such sections are the following :—

Spawood Mine.

Section taken in the main headway, 900 yards from entrance.

	Thickness. In.	Fe. per cent.	SiO_2. per cent.	
Shale and Dogger	—	—	—	—
Sulphur Band	6 to 8	—	—	—
Top Block Ironstone	33	27·6	15·5	Total ironstone 6 ft. 9 in. with 28 per cent. Fe and 14·8 per cent. SiO_2
Dogger	6	26·6	19·0	
Shale	6	—	—	
Dogger	6	27·3	17·1	
Bottom Block Ironstone	36	28·9	13·2	
Black Hard Shale	24	—	—	—
Pecten Seam	—	—	—	—

Spawood Mine.

Section taken near the Belmont boundary, 1,700 yards south-west of preceding section.

	Thickness. In.	Fe. Per Cent.	SiO_2 Per Cent.	(As Mined.)
Shale, Dogger and Sulphur Band	—	—	—	—
Top Block Ironstone	30	27·3	14·2	Total ironstone 4 ft. 5 in. with 26.6 per cent. Fe and 17·7 per cent. SiO_2
Shale	18	—	—	
Dogger	14	24·3	22·7	
Bottom Block Ironstone	9	28·1	21·1	
Black Hard Shale	—	—	—	

In the country to the dip of the belt in which the mines are situated, the ironstone is even more split up by shale-intercalations and its iron-content further diminished.

Some explanation of the terms used in the above sections is perhaps needed. There appears to be in the constituent layers of the Main Seam every gradation between a siliceous clay-shale with small iron-content and a calcareous ironstone with smaller but still notable proportions of silica and alumina. The bed known as the "Black Hard" and the layers of dogger† represent such gradations, the Black Hard being a ferruginous shale with few laminations and the dogger a ferruginous mudstone entirely devoid of laminated structure. The Black Hard which underlies the Main Seam is on account of its high silica and alumina content rarely ever worked, although it contains a notable proportion of iron. An analysis of a Spawood sample gave 23 per cent. of iron and 27·4 per cent. of insoluble matter. At Eston, however, it is worked with the overlying ironstone, the total thickness broken at that mine being 14 ft. (possibly this may in places include the Pecten Seam).

The doggers occur as layers immediately above and below the Top Block ironstone and above the Bottom Block ironstone; also as irregularly-shaped masses in the ironstone itself, giving it in places a spotted or mottled appearance. As shown in the above sections they often contain almost as much iron as the ironstone itself, but are invariably higher in silica and alumina.

The Sulphur Band is a layer of disseminated pyrites, a few inches in thickness, which occurs immediately above the Top Block ironstone. It usually comes away with the ironstone, and care has to be exercised either to leave it in the mine or to remove it on the picking belts.

The ironstone, as mined, is a dark-coloured greyish-green rock, in which the little round grains (ooliths) are easily discernible with the aid of a magnifying glass. The researches of A. Dick‡ have shown that the green colour of the stone is due to the presence of a silicate containing both oxides of iron, further that the ooliths consist in the main of carbonate of iron, but that they have an exterior shell of soluble silica. These siliceous shells are very clearly seen in the beautiful photographs taken by Mr. Stead§ of material that had been treated with hydrochloric acid.

The origin of the ironstone is still open to argument; but the view chiefly held is that first formulated by

* Sections of the Main Seam at its outcrop are fully described in Tate and Blake's "Yorkshire Lias."

* I am indebted for this information to Mr. H. E. Wright of Sir B. Samuelson and Co., Limited.

† I am using this term in the sense in which it is used by the Cleveland miners, and not, as is customary among geologists, as a synonym for the Top or Oolite Seam.

‡ A. Dick, "Iron Ores of Great Britain," 1856, page 97, and *Quarterly Journal of the Geological Society*, 1856, page 357.

§ J. E. Stead, "Cleveland Ironstone and Iron," Cleveland Institution of Engineers, 1910, page 7.

TABLE I.—AVERAGE WEEKLY OUTPUT OF IRON ORE FROM MINES IN THE CLEVELAND DISTRICT DURING THE LAST QUARTER OF 1917, AND TOTAL PRODUCTION FOR THE YEAR 1917.

Owner.	Mine.	Average Weekly Output.		Total Output, 1917.	
		Mine. Tons.	Group. Tons.	Mine. Tons.	Group. Tons.
Bolckow, Vaughan and Co., Limited	Eston	9,785		508,828	
	N. Skelton	7,098		369,068	
	S. Skelton	5,725		297,707	
	Belmont	4,688	27,296	243,785	1,419,388
Pease and Partners, Limited	Loftus	7,686		399,662	
	Lingdale	3,813		198,295	
	Upleatham	4,589		238,633	
	Ayton	2,107	18,195	109,556	946,146
Bell Brothers, Limited	Lumpsey and Carlinhow	9,875		513,480	
	Park Pit	4,027		209,422	
	Skelton	1,467	15,369	76,290	799,192
Dorman, Long and Co.	Kilton	3,304	3,034	157,744	157,744
Sir B. Samuelson and Co., Limited	Spawood	8,265	8,265	429,799	429,799
Tees Furnace Company, Limited	Roseberry	3,915		203,594	
	Ayton Banks	1,451	5,366	75,453	279,047
Cargo Fleet Iron Company	Liverton	3,228	3,228	167,874	167,874
Cochrane and Co., Limited	Stanghow	3,077	3,077	160,004	160,004
Skinningrove Iron Company, Limited	Boulby	2,554	2,554	132,790	132,790
Grinkle Park Mining Company, Limited (Palmer's Shipbuilding and Iron Company)	Grinkle Park	3,007	3,007	156,384	156,384
Morrison and Co.	Brotton	1,346	1,346	70,006	70,006
			90,737		4,718,374
Lascelles and Shepherd	East Rosedale	1,759	1,759	91,487	91,487
	Average output per week		92,496		
	Total output for 1917				4,809,861

TABLE II.—*Output from the Cleveland Ironstone Mines for each Year from* 1860 *to* 1917.*

Year.	Tons.	Year.	Tons.
1860	1,471,319	1889	5,728,314
1861	1,242,514	1890	5,617,573
1862	1,689,966	1891	5,128,303
1863	2,078,806	1892	3,411,400†
1864	2,401,890	1893	4,625,520
1865	2,762,359	1894	5,048,966
1866	2,809,061	1895	5,285,617
1867	2,739,039	1896	5,678,366
1868	2,785,307	1897	5,679,153
1869	3,094,678	1898	5,730,413
1870	4,072,888	1899	5,612,742
1871	4,581,901	1900	5,493,733
1872	4,974,950	1901	5,100,823
1873	5,617,014	1902	5,396,670
1874	5,614,322	1903	5,668,296
1875	6,121,794	1904	5,719,607
1876	6,562,000	1905	5,934,283
1877	6,284,545	1906	6,102,223
1878	5,605,639	1907	6,240,103
1879	4,750,000	1908	6,072,933
1880	6,486,654	1909	6,191,172
1881	6,538,471	1910	6,152,823
1882	6,326,314	1911	6,049,815
1883	6,756,055	1912	5,158,440‡
1884	6,052,008	1913	6,010,800
1885	5,932,244	1914	5,574,788
1886	5,370,279	1915	4,746,293
1887	4,980,421	1916	4,315,765
1888	5,395,942	1917	4,907,016

* The outputs for the last twenty-five years were furnished by the Cleveland Mine-Owners' Association. Those for the previous years are taken from Kendall's "Iron Ores of Great Britain and Ireland."
† Durham coal strike (three months).
‡ National Coal strike (five weeks).

Dr. Sorby,* namely, that it is a case of metasomatic replacement of carbonate of lime by carbonate of iron, subsequently to the deposition of the bed as an oolitic limestone.

Method of Working.—The mines are worked on the bord-and-pillar system. In most mines rope haulage is used, the direction of the roads in relation to the dip of the seam being so adjusted as to give sufficient fall to enable the trains of empty pit-tubs to return by gravitation and carry the tail rope with them. The rope haulages are actuated electrically.

From the main roads secondary roads branch diagonally both to the rise and to the dip. Those to the rise are self-acting inclines. In the case of the roads to the dip the full tubs are raised by auxiliary rope haulages, the empties being returned by gravitation. In the large and older mines the haulage roads total a score of miles or more. Separated from them by 20-yard pillars are parallel roads which are used by men and horses in travelling to and from their work and also serve as air-ways.

The diagonal roads are connected by cross-headings, and pillaring is commenced by driving the bords. In the best practice, the pillars are 20 yards square with 25-yard centres, 40 per cent. of the stone being taken out in the first workings. Where the pillars have been "robbed," by enlarging the bords and splitting the pillars a higher percentage of stone is won in the first working, but there is an ultimate loss, since the crushing of the stone under the increased pressure prevents the complete removal of the pillars during the second working.

The second workings can only begin when the haulage roads reach a boundary, for the working of the "brokens" (*i.e.*, the extraction of the pillars) involves the fall of the roof to goaf, unless the natural conditions (such as water in the overlying strata) are considered unfavourable to this method of working. In this case, the roof is supported by "stowing" the shale picked out from the seam during the first working, or, if this does not suffice, by bringing filling material from the dumps at the surface.

According to returns made for the year 1917 to the Cleveland Mine Owners' Association, 91 per cent. of the stone is won by ratchet or rotary hand drills, 7 per cent. by power-driven machine drills and 2 per cent. by ordinary jumper drills. The blasting material is black powder.

In the older mines development is, to all intents and purposes, complete, and work is now practically confined to the "brokens" (*i.e.*, the extraction of the pillars). The total reserves of the 22 mines at present being worked are estimated at 192,500,000 tons,* which, at the present rate of production, is equal to thirty-five years' life.

According to returns made to the Cleveland Mine Managers' Association for all mines, including East Rosedale, which is working on the Top or Oolite Seam, the production last year amounted to 4,809,861 tons.

The ownership and weekly and annual output (1917) of the Cleveland mines is shown in Table I above, and Table II gives the production of the district for each year from 1860 to 1917 inclusive.

With the exception of the last two mines, the output goes to blast furnaces worked by the mine owners. The output from Brotton goes to Messrs. Cochrane and Co.'s Ormesby works, and that of East Rosedale to Sir B. Samuelson's works.

(To be continued.)

* H. C. Sorby, Anniversary Address, Geological Society, vol. xxxv., page 84, and Proceedings of the Geological Society of Yorkshire, 1856, vol. iii, page 457.

* From information obtained for the Ministry of Munitions by Mr. G. E. Stephenson.

DETERMINATION OF OXYGEN IN IRON.—A method for the quantitative determination of oxygen in iron was proposed by Ledebur in 1882. He heated the iron in a current of hydrogen and absorbed the water formed by the combination of part of the hydrogen with the oxygen in the iron with the aid of phosphorus pentoxide. The method and similar methods have found little application, however, because the analysis takes a long time, four or five hours, and Ledebur was himself doubtful as to its reliability. The oxygen may be present in the iron as such, or it may be combined with the iron and the various other elements in the iron, and those compounds are not reducible with the same ease. It is assumed that manganous oxide and silicates, likely to be present as slag enclosures, are not reduced by hydrogen at temperatures of 900 deg. or 1,000 deg. C., which are generally the practical limit of such analyses, while ferrous iron is reduced. At the same time it would be highly desirable to follow the advancing disoxidation of metallurgical processes by analytical means, and to have some means of determining the occluded oxygen in iron, to which some metallurgists attribute considerable importance. It is therefore interesting to note that P. Oberhoffer, of Breslau, claims to have simplified the Ledebur method so that a complete analysis can be made within an hour and that metallurgical processes can be watched. The apparatus (Stahl und Eisen, February 7, 1918) consists of a hydrogen generator, apparatus for purifying this gas, a mercury air pump of the Beutell type, a combustion tube of silica-glass and a tubular electric furnace. The iron specimens, turnings as a rule, are heated in the tube by means of the burner to facilitate the complete evacuation of the tube, the hydrogen is then admitted, and the furnace slipped over the tube which is raised to a temperature of 950 deg. C.

THE EFFECT OF COLD-WORK ON THE DIVORCE OF PEARLITE.*

By J. H. WHITELEY, Stockton-on-Tees.

THE observations here recorded were made in continuation of the study of the Eggertz colour test for combined carbon. The author's previous work on the subject has recently been presented as a Carnegie Research Memoir. It is there shown that the colour-carbon given by a cold-worked sample of steel is generally considerably higher than that given by the same material in an unstrained condition, and the experimental evidence suggests that the effect of cold-work is to produce an alteration in the degree of electrochemical action between the ferrite and the cementite while the sample is dissolving. It was thus to be expected that, if the strain due to cold-working were removed by suitable annealing, the colour-carbon of the steel would revert to the lower value given by the sample in the unstrained condition. Experiments were made, therefore, in which drillings of pearlitic steels were annealed *in vacuo* for about 1 hour at 650 deg. C.; instead of a decrease in the value of the colour-carbon being obtained, however, it was found that in every case there was a large increase. Two examples are given in Table I; to produce the same increase in the colour values of the unstrained steels, a very prolonged heating at the above temperature would be required.

TABLE I.

Sample.	A.	B.
	Per Cent.	Per Cent.
Carbon by combustion	0·59	0·78
Silicon	0·105	0·065
Phosphorus	0·025	0·022
Sulphur	0·035	0·033
Manganese	0·77	0·75
Carbon by colour in cut (unstrained) pieces	0·49	0·69
Carbon by colour in cut drillings	0·59	0·78*
Carbon by colour in cut drillings annealed at 650 deg. C.	0·70	0·94

* Taken as standard.

Since the size and shape of the cementite particles had been found to be closely related with the colour-carbon result, the next step was to prepare samples of these two steels in the strained and annealed conditions for microscopic examination. Bars about 2 in. long and ½ in. square in section were cut from each, and these were hammered down to ¼ in. square section under a small steam hammer. During this treatment the bars were kept at a temperature below 100 deg. C. by frequently dipping them in cold water. Sections were then cut and polished and the cementite stained by immersing the specimens in a hot solution of sodium picrate for about 15 minutes.†

A typical example of the pearlite in the hammered section of sample B, under a magnification of 1,250 diameters, is shown in photograph No. 1. When compared with the pearlite in the unstrained steel, the carbide laminæ appeared to be more irregular in outline owing to distortion, but no other change could be seen. A similar effect was observed in the pearlite of the hammered section of sample A.‡

Portions of these cold-worked bars, together with sections of each steel in the unstrained condition, were next heated for 1 hour at 650 deg. C. The colour-carbons given by cut pieces of the strained sections before and after annealing were then obtained, the unannealed drillings of sample B being used as a standard. The results are given in Table II, and it will be seen that in the annealed pieces from the hammered bars an increase in the colour values of the carbon is obtained which is quite equal to that given by a similar treatment of the drillings (Table I). There can be no doubt, therefore, that with both types of cold-working annealing at 650 deg. C. produces the same effect.

TABLE II.

Sample.	A.	B.
	Per Cent.	Per Cent.
Carbon by combustion	0·59	0·78
Carbon by colour in hammered bar	0·57	0·75
Carbon by colour in hammered bar after annealing 1 hour at 650 deg. C.	0·69	0·94
Carbon by colour in piece quenched and tempered 2 hours at 660 deg. C.	0·70	0·96

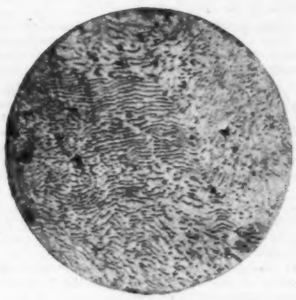
* Paper read before the Iron and Steel Institute, May 3, 1918.

† In preparing sections of finely pearlitic steels, when sodium picrate is to be used, care must be taken to prevent the least drag or flow of the ferrite over the cementite laminæ, or the result may be somewhat misleading. After polishing with diamantine on a Selvyt cloth, the sections can be very lightly etched with alcoholic picric acid to remove any surface flow and then gently repolished.

‡ The great advantage of using sodium picrate in developing the carbide structure of these finely pearlitic steels is seen on comparing photograph No. 1 with photograph No. 2. The latter shows the structure obtained after etching the same steel for about 15 seconds with a solution of picric acid in alcohol. Here only traces of the lamellæ appear, and under a magnification of 500 diameters these were not visible. The steel then appeared to be entirely "sorbitic" in character, and as such it would have to be described if the classification proposed by Howe and Levy (Journal of the Iron and Steel Institute, 1916, No. II) were adopted.

THE EFFECT OF COLD WORKING ON THE DIVORCE OF PEARLITE.

(*For Description, see opposite Page.*)



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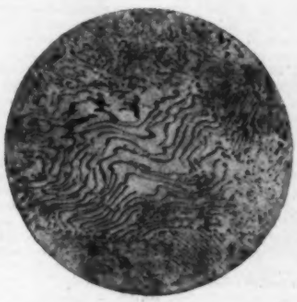

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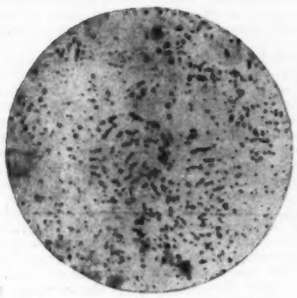

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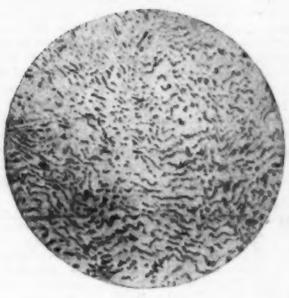

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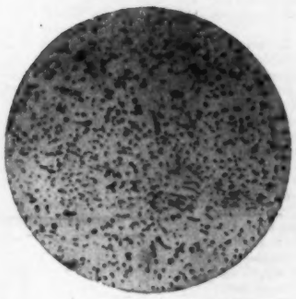

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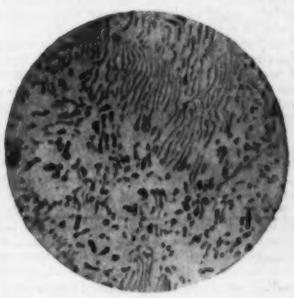
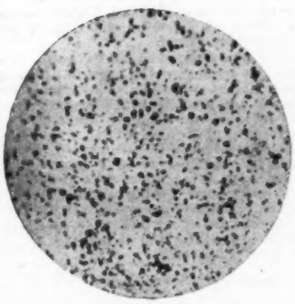


No. 8.



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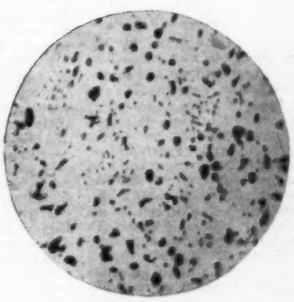
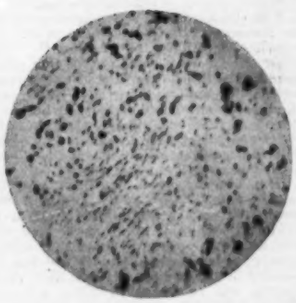
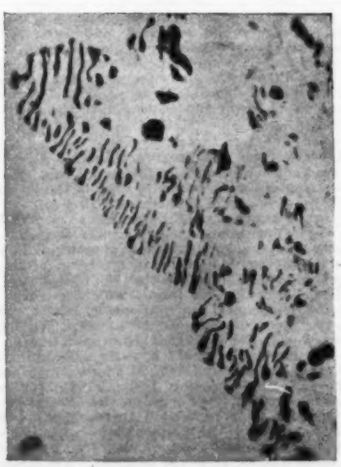


No. 10.

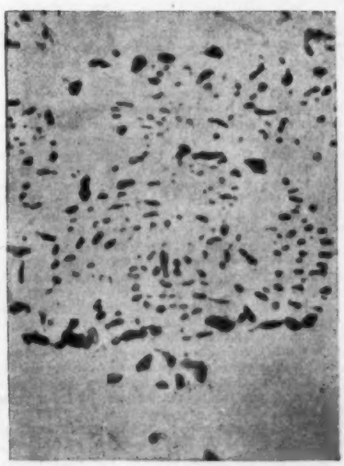
No. 12.



No. 13.



No. 11.



No. 14.

No. 1. Pearlite in hammered bar of sample B (carbon by combustion = 0.78 per cent.).
No. 2. Ditto ditto (etched with picric acid).
No. 3. Ditto ditto.
No. 4. Same area as shown in No. 3 after heating at 600 deg. Cent. for 15 minutes.
No. 5. Same area as shown in Nos. 3 and 4 after heating at 660 deg. Cent. for 15 minutes.
No. 6. Pearlite in hammered bar of sample B after heating at 550 deg. Cent. for 15 minutes.
No. 7. Pearlite in hammered bar of sample B after heating at 660 deg. Cent. only for 15 min.
No. 8. Pearlite in sample B (unstrained) after heating for 40 hours at 680 deg. Cent.
No. 9. Sample B after quenching and tempering for 2 hours at 660 deg. Cent.
No. 10. Hammered section of sample B after heating for 2½ hours at 680 deg. Cent.
No. 11. Pearlite in annealed casting (c.c. 0.40 per cent.) after hammering.
No. 12. Ditto (unstrained) after heating for 4 hours at 680 deg. Cent.
No. 13. Lightly hammered section of sample B after heating for 2 hours at 680 deg. Cent.
No. 14. Section of the annealed casting after hammering and heating for 4 hours at 680 deg. Cent.

ALL STAINED WITH SODIUM PICRATE EXCEPT No. 2, WHICH WAS ETCHED WITH PICRIC ACID.

MAGNIFIED 1250 DIAMETERS AND ENLARGED BY ONE-FOURTH

On examining sections of the annealed cold-worked bars under the microscope, it was found that almost the whole of the pearlite had been divorced. In both cases practically all the cementite was now in the form of fine rounded particles uniformly distributed in the manner shown in photograph No. 7. No such change had occurred in the unstrained sections which were annealed at the same time; in fact, very little alteration in the pearlite could be detected. Howe and Levy* have shown that, as the carbon approaches eutectoid proportions, the speed at which divorcing takes place in unstrained steels is greatly lengthened, and to effect a complete divorce in such steels a very prolonged heating at about 690 deg. C. is required. An idea of the length of time necessary can be gathered from photograph No. 8, which was taken from a section of sample B after it had been heated at 680 deg. C. for 40 hours; much of the pearlite still remains. It is thus clear that the rapid divorce of the pearlite on annealing the hammered sections must have been due in some way to the cold-working of the metal.

In order to study this effect more closely, a small section of the hammered bar of sample B was next heated *in vacuo* for periods of 15 minutes† at successive temperatures between 450 deg. C. and 690 deg. C.

1. 450 deg. C.—No change was observed. (The structure still appeared to be unaltered even after a further 2 hours' heating.)

2. 500 deg. C.—The laminæ showed in certain areas a decided tendency to break up. An unaltered part was photographed (photograph No. 3) and its position on the surface was marked so that the break-up of this area could be followed.

3. 550 deg. C.—The selected area was still unchanged, but the bulk of the pearlite showed unmistakable signs of breaking up. To make certain that the same change was occurring throughout, the section was cut in two and a fresh surface prepared. Photograph No. 6 shows the typical broken carbide structure of this section.

4. 600 deg. C.—The changes which had taken place in the selected area (photograph No. 3) are seen in photograph No. 4. The greater part of the pearlite in the section had been completely divorced, the cementite being now in the form of minute rounded particles.

5. 660 deg. C.—Photograph No. 5; the last remaining laminæ of the selected area had broken up, and the divorce was now almost complete. Another section from the same cold-worked bar was next heated for 15 minutes at this temperature only. Here again the greater part of the pearlite was found to have been completely divorced in this short time, as shown in photograph No. 7; only a few areas remained, and after a further 2 hours' heating these also had vanished, and the whole of the cementite was now uniformly distributed, as seen in photograph No. 10.

A final experiment was made by heating a section of the hammered bar and a piece of the unstrained steel together for 4 hours at 600 deg. C. The very marked effect of cold-work on the divorce of pearlite was again seen, for while the pearlite of the unstrained steel was practically unaltered by this treatment, that of the hammered section had completely broken up. It is thus clear from these experiments that not only is the divorce of fine pearlite greatly accelerated by cold-work, but also that the temperature at which the divorce takes place is considerably lowered.

It has been shown by Howe and Levy‡ that, on annealing unstrained steels at about 680 deg. C., the pearlite areas are not all divorced at the same rate. Evidently this rule applies in the case of strained steels also, as it was repeatedly found that while in 15 minutes' heating, at temperatures above 600 deg. C., much of the pearlite in the hammered bars had vanished, 2 hours' heating was necessary to effect a complete break-up. The process of divorce may be regarded as occurring in two stages; each layer of carbide is first broken into several parts, and these then ball up under the influence of surface tension. No clear evidence could be obtained as to whether the initial breaking of the laminæ begins gradually by thinning in certain places or takes place suddenly. The fact that so much of the pearlite can be divorced in 15 minutes strongly indicates that when once the laminæ are fractured the subsequent spheroidising of the broken parts is rapidly completed.

In order to obtain some idea of the amount of deformation required to bring about this quick divorce on annealing, a bar of ½ in. square section from sample B was given two light blows only under the steam hammer so as to reduce the sectional area to about $\frac{7}{8}$ in. square. The bar was then heated for 2 hours at 680 deg. C. On examination, only faint traces of the original pearlite could be found, the carbide now being in the granular form; a typical area is shown in photograph No. 13. It is possible that on further investigation this acceleration of divorce on annealing may prove to be a delicate test for small amounts of strain in pearlitic steels.

Some similar experiments were now made on the coarse and partly divorced pearlite in a thoroughly annealed casting of the following analysis:—

	Per Cent.
Combined carbon	0·40
Silicon	0·39
Phosphorus	0·048
Sulphur	0·034
Manganese	0·510

A bar, ½ in. square in section, was heavily cold-worked under the steam hammer as in the previous cases. The typical pearlite structure of this steel after hammering is shown in photograph No. 11. A section was next heated for 15 minutes at 680 deg. C., but no change could be detected after this treatment. On heating for 2 hours at the same temperature, however, the pearlitic structure was seen to be breaking up, and after 2 hours' more heating it had completely vanished, the cementite being now distributed through the steel in the form of large spheroids, as shown in photograph No. 14. An unstrained section of the steel was annealed along with the above, but even after 4 hours' heating scarcely any change could be observed; the pearlite still remained, as is shown in photograph No. 12.

There can be no doubt, therefore, that the divorcing of coarse pearlite is also accelerated by cold-work, but the break-up is evidently much slower than in the case of the finer forms.

Comparison with Tempered Steels.—The spheroidal carbide structure which is obtained on annealing finely pearlitic steels after deformation by cold-work cannot be distinguished under the microscope from the so-called "granular pearlite" of tempered steels unless traces of the pearlite laminæ are still present. Photograph No. 9 shows the form of the carbide in a section of sample B after quenching from 800 deg. C. and tempering for 2 hours at 660 deg. C. On comparing with photograph No. 10, the similarity of the structures is at once seen. This similarity is also indicated by the high colour values which a steel will yield in either condition when tested against the normal drillings. Four typical instances are seen in the last two examples given in Table II; the carbide in these four annealed sections was in the spheroidal form seen in photograph No. 9, and in each case the colour value is about 20 per cent. higher than that of the drillings of the pearlitic sample. The steady increase in the colour values which can be obtained by gradually annealing a strained steel is also shown in Table III. Drillings of sample B were heated for 15 minutes and 2 hours at the respective temperatures and then colour-tested for carbon against the unannealed drillings which were taken as standard. The results make it quite clear that, as the spheroidising of the carbide proceeds, the colour value rises.

TABLE III.—*Showing the Increase in Colour Values obtained by Annealing Steel Drillings.*

T°.	¼ Hour.	2 Hours.
Deg. C.	Per Cent.	Per Cent.
—	0·78	0·78
440	—	0·80
500	0·82	0·86
550	0·85	0·89
600	0·90	0·94
670	0·92	0·94

Not only are the high colour values given by the spheroidal cementite comparable in the two conditions obtained by annealing quenched and cold-worked steels, but also other points of similarity appear. It was repeatedly noticed that cut pieces of steels annealed at 650 deg. C., after either quenching or straining, dissolved much quicker in the dilute nitric acid than cut pieces of the same steel in the pearlitic state. Furthermore, it has been found that the quantity of hydrocyanic acid given off from the Eggertz test solutions of samples containing only spheroidal cementite is invariably much less than the quantity evolved under similar conditions from solutions of the pearlitic steels. Thus both microscopic and chemical tests indicate that on annealing a strained steel for about 2 hours at 650 deg. C., its condition is then very similar to the condition obtained by annealing a quenched steel in the same way, and it seems reasonable to infer that, given an equality in grain-size, the physical properties of the two forms should be closely alike.

Possible Explanations.—The striking effect of cold-work in causing the rapid divorce of pearlite on annealing was at first attributed to the fracturing of the films of brittle cementite by hammering. The most careful microscopic examination of the hammered sections failed, however, to reveal any traces of such fracturing even in places where the films appeared to be much distorted. Moreover, if the laminæ had been uniformly cracked, there seems to be no reason why they should not all spheroidise at about the same rate, whereas it was repeatedly found that some areas were divorced at least eight times as fast as others. The flexibility of these fine films under plastic deformation has been observed by Howe and Levy,* who remark as follows: "That these extremely thin lamellæ of cementite should thus bend without breaking is natural, reminding us of the great flexibility of sufficiently thin threads of slag wool or glass, substances which in thick masses are so inflexible." Thus it would seem that the initial rupture of the cementite lamellæ is not the direct result of mechanical deformation; the films are merely crumpled or distorted by the cold-work, and before they begin to break the steel must be heated to about 500 deg. C. The cause of the accelerated divorce of the pearlite in strained steels must therefore be sought in some other direction, and a much closer study of the problem will be necessary before an entirely satisfactory solution is obtained. Among possible explanations, at least three can be suggested.

1. Referring to the cementite lamellæ which are bent without breaking, H. Le Chatelier remarks as follows:† "Must they not have been then in elastic tension? Their solubility in ferrite should be increased as a consequence. If, then, a steel in which cementite is thus deformed be heated to a temperature near the point of recalescence, the curved lamellæ ought to disappear and recrystallise out, but under what form? As lamellæ or as rounded grains? A crystal soluble in water, if subjected to mechanical stress, has its solubility increased. The same is necessarily true in metals."

2. The fact that on long annealing unstrained pearlitic steels at 680 deg. C., the cementite laminæ eventually ball up indicates that these films are in a metastable condition. It has been shown by Goerens* that strain in iron due to cold-work begins to be removed rapidly on heating at 520 deg. C. This temperature practically coincides with that at which the rapid divorce resulting from cold-work starts. Now the removal of the cold-work strains is known to be accompanied by small changes in volume, and also by some recrystallisation and rearrangement of the grain-boundaries. Such changes must certainly involve local variations in the forces of surface tension at the cementite-ferrite interfaces; the metastable condition of the cementite films is thereby disturbed, with the result that the process of divorce proceeds at an accelerated pace.

It should be observed here that before this divorce can take place, the crystal rigidity of both the ferrite and cementite must be sufficiently relaxed to allow it, as each constituent necessarily flows. So long as one is rigid the other cannot alter its shape. The fact that the removal of cold-work strains and the rapid divorce of the pearlite begin at about the same temperature lends strong support to the view that the point at which the divorce can begin is determined by the mobility of the ferrite.

3. The break-up of the cementite films may be regarded simply as an effect of surface tension, and may be compared with the behaviour of a thin cylindrical stream of water issuing from a tap. It is well known that small vibrations which bring about slight deformations in the metastable cylindrical form at once cause the stream to break up into a line of drops. Similarly, the thin films of cementite, though their surfaces are not stable, may persist for a long time in a metastable condition on heating at temperatures below the recalescence point; but if they have been deformed by cold-work the films, no longer metastable, break up, and the parts contract under the surface-tension forces until the stable configuration of a series of spherical drops is reached. The speed of the readjustment will, of course, depend upon the plasticity of the crystals and probably, upon the thickness of the films.

SUMMARY.

1. It has been shown that by annealing drillings and other cold-worked samples of pearlitic steels for a short time below the critical point (690 deg. C.) the values for the combined carbon as given by the Eggertz colour test can be considerably raised.

2. The effect of annealing such cold-worked steels is to cause the carbide laminæ of the pearlite to break up quickly into a series of spheroids. The change begins at about 500 deg. C. and proceeds with increasing rapidity as the temperature is raised; on annealing at 680 deg. C. this pearlite divorce can be completed in less than 2 hours even in a eutectoid steel when the laminæ are very thin; very coarse pearlite requires about 4 hours' heating. As is well known, to bring about this result in the unstrained steel many days' heating is required.

3. The condition obtained by annealing at 650 deg. C., after cold-working the metal, resembles in several respects that obtained by quenching and tempering for about 2 hours at the same temperature.

RUSTLESS IRON FITTINGS.—A new company has been formed called Rustless Iron (Cowper Coles Process), Limited. It has acquired works at Shepperton-on-Thames, with a railway siding into the premises. The company will specialise in rustless fittings of all descriptions, especially for seaplanes and aeroplanes, also railway and ships' fittings; it has, further, acquired some important improvements in Sherardising from Mr. Cowper Coles, also a new process called "doxidising," which is specially suitable for iron and steel work exposed to salt water, as the zinc coating itself is protected from corrosion.

MATERIAL FOR LOCOMOTIVE BOILERS, AUSTRALIA.—We read in *The Board of Trade Journal*, that H.M. Trade Commissioner has forwarded a copy of the specification and form of tender in connection with a call for tenders by the Commonwealth Department of Works and Railways (Transportation and Stores Branch), for the manufacture, supply and delivery of material for 10 "G" class locomotive boilers of all steel, or, alternatively, copper and steel. (Specification No. CME/258.) Sealed tenders, on the proper forms, will be received at the office of the General Superintendent, Melbourne, up to June 6. Each tender must be accompanied by a preliminary deposit calculated on the following scale: For amounts under 200*l.*, 2*l.*; for amounts exceeding 200*l.*, and not exceeding 500*l.*, 5*l.*; for amounts exceeding 500*l.*, and not exceeding 1,000*l.*, 10*l.*; for amounts exceeding 1,000*l.*, 1 per cent. on the amount of tender. The tenderer, if not resident in Australia, or if a company registered outside the Commonwealth, must name an agent in Australia to receive notifications of acceptance and other notices under the contract. The specification may be consulted by British manufacturers at the inquiry office of the Department of Overseas Trade (Development and Intelligence).

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* Proceedings of the Cleveland Institution of Engineers, 1914.

† From 3 minutes to 5 minutes of this period were taken up in heating the specimen to the required temperature.

‡ Proceedings of the Cleveland Institution of Engineers, 1914.

* Transactions of the American Institution of Mining Engineers, 1914, vol. l, page 542.

† Discussion of Howe and Levy's paper, Transactions of the American Institution of Mining Engineers, 1914, vol. l.

* Iron and Steel Institute: Carnegie Scholarship Memoirs, 1911, vol. iii, page 383.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

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The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c. of the Communicators are given in italics.

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Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

AGRICULTURAL APPLIANCES.

113,255. J. Bamford, and C. Bamford, Uttoxeter. Hay Rakes and Swath Turners. (2 *Figs.*) January 8, 1917.—This invention has reference to side delivery hay-raking machines and swath-turning machines of that kind in which the rake bar is furnished with pendent tines which are carried by and between two eccentrically-placed revolving reels or spiders, and have combined rotary and endwise movements imparted to them across the path of the machine, the tines always pointing towards the ground at every part of their revolution. According to this invention, the rake bar extension 2, which is arranged to fold on a horizontal plane against the main portion B of the rake bar, is jointed on to the upright supporting pin 3, which carries the end

Fig. 1.

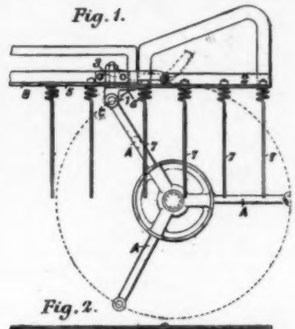


Fig. 2.

of the main portion B of the rake bar. This extension bar 2 is preferably made of angle section with its lower horizontal flange 4 arranged underneath the flange 5 of the main portion B of the rake bar and when turned to its extended position it rests on a lateral bracket like extension 6, which is formed on the side of the rake bar supporting fitting C, which fits and turns on the substantially horizontal crank-pin 1 of the reel or spider A. Thus the extension bar 2, with its tines 7, can be turned horizontally about the supporting pin 3 as a centre, so as to be either near the main portion B of the rake bar, as indicated by the dotted lines in Fig. 2, or turned so as to stand out in a line therewith ready for use, as shown by full lines in Figs. 1 and 2. (*Sealed.*)

113,117. J. Bamford, and C. J. Bamford, Uttoxeter. Hay Rakes and Swath Turners. (6 *Figs.*) January 8, 1917.—This invention has reference to side-delivery hay-raking machines and swath-turning machines of that kind in which the rake bar is furnished with pendent tines which are carried by and between two eccentrically-placed revolving reels or spiders, and have combined rotary and endwise movements imparted to them across the path of the machine, the tines always pointing towards the ground at every part of their revolution. A is one of the reels or spiders, B is a portion of one of the rake bars which

Fig. 1.

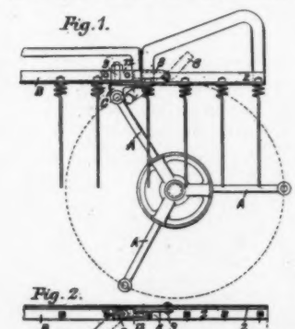
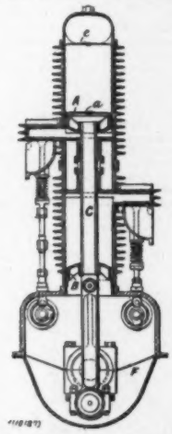


Fig. 2.

is mounted on the upright pin 3 of the supporting fitting C, which is jointed to the crank-pin-like end of the arms of the reel or spider A. According to this invention, when the rake bar extension 2 is arranged to fold in a horizontal plane against the main portion B of the rake bar, or to turn so as to stand out in a line therewith ready for use as shown in the full lines, there is provided, in order to lock the extension bar 2 rigid in its extended position, a locking pin or latch or a spring catch arranged either on the main portion B of the rake bar or on the supporting bracket of the same, or on the extension bar 2 itself, and arranged so as to be permanently attached to one of said parts and effectually secure the extension bar rigidly in position when turned to its extended position ready for use. This locking pin or latch or catch or the like may be arranged in various ways, but preferably a latch 8 is employed which is a flat section bar secured by a fulcrum-pin 9 to the upright flange of the rake bar extension 2 and adapted to turn about the same so as to project over the junction line of the extension bar 2 and the main bar B, and engage in a slot or recess which is formed in the bracket or block 12, which is riveted to the upright flange of the main portion B of the rake bar, and forms a bearing for the upright pin 3. Thus, when this latch 8 is turned down as shown in the full lines, it locks the extension bar 2 rigidly in a line with the rake bar B, and when the latch 8 is turned up as indicated by the dotted lines the extension bar 2 is free to be turned about its joint and folded as aforesaid. It will be evident that as a modification, and for the purpose of locking the rake bar extension 2 when extended as aforesaid, the joint fitting 6 of the main portion of the rake bar could be furnished with a spring catch-pin to engage with a hole or recess in the bottom flange 4 of the rake bar extension 2 when the latter is turned to its extended position as aforesaid. (*Sealed.*)

GAS ENGINES, PRODUCERS, HOLDERS, &c.

113,127. C. R. B. Frost, and G. Thorne, Junior, Wolverhampton. Internal-Combustion Engines. (2 *Figs.*) February 3, 1917.—This invention relates to the type of internal-combustion engine in which two pistons are connected together, tandem fashion, by a common piston rod. According to this invention, the piston rod C of a pair of tandem pistons A, B of an engine of the above type is hollow, as has been previously proposed, but at the back end of the rod, or closing an opening at the back of the rear piston with which the back end of the rod communicates, is fitted a valve *d* which opens outwards only, and at the back end of the rear cylinder is fitted a valve *e* which also opens outwards only, and in the side of the crank-case F, or in other convenient position of the crank-case, is an opening



through which air may be drawn. During each stroke of the tandem pistons in a direction towards the crankshaft, the valve *e* closes and remains closed, and the valve *d* opens and allows air to pass through from the crank-case into the space behind the rear piston. On the return stroke, the valve *d* closes, and the air at the back of the piston A is forced out through the valve *e* and, at the same time, further air is drawn into the crank-case F. The air which is thus passed through the crank-case and piston rod tends to cool the connecting rod bearings, the pistons, the interior surfaces of the cylinders, and the piston rod, and may be employed in conjunction with ordinary means of air, or water, cooling, such as have been used with internal-combustion engines. (*Sealed.*)

113,163. Vickers, Limited, and T. K. North, Westminster, London. Internal-Combustion Engines. (7 *Figs.*) March 6, 1917.—This invention relates to fuel pumps for multi-cylinder internal-combustion engines of the kind in which a rotatable member is provided with a series of pump cylinders and plungers, the strokes of which are effected by an eccentric ring or cam face against which the plungers act. According to this invention, the rotatable member B is provided with a distributing port *b*1 which leads the fuel from the pump cylinders *b* to a fuel distributor D, from which it passes to the engine cylinders in succession. In the preferred construction, the rotatable

Fig. 1.

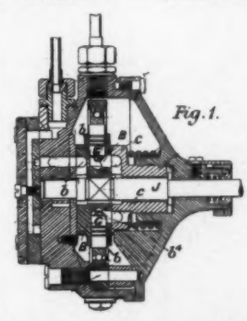


Fig. 2.

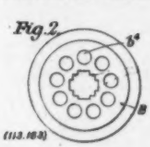
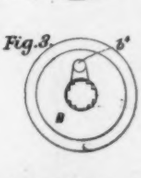


Fig. 3.



member B is formed at one face with fuel ports *b*4 leading from the inner end of each cylinder to inlet and delivery ports in the face of a stationary disc or plate C in the pump chamber, from which the fuel supply is drawn, the fuel on delivery passing through a passage in the rotatable member B to the distribution port *b*1 in the opposite face, which port moves in succession over fuel ports arranged in a ring in a fixed distribution plate D serving to distribute the fuel to the corresponding feed pipes of the engine cylinders. The rotatable member B may be in the form of a thick disc mounted upon an engine-driven shaft J passing through the pump casing, the disc being bored with a series of radial cylinders at the inner ends of which are the fuel ports *b*4 opening through one face of the disc. The pump plungers G project through the outer ends of the cylinders to meet an eccentric ring F, the eccentricity of which can be regulated by pivoting the ring at one side and angularly adjusting it around the pivot by a screw passing through the casing and set from outside. (*Accepted February* 20, 1918.)

113,203. E. W. Harvey, Westminster, London, and E. N. Wright, Ettingshall, Wolverhampton. Gas Producers. (6 *Figs.*) May 10, 1917.—This invention has reference to mechanical feeders for gas producers of the kind in which the substance to be fed gravitates from a hopper through a delivery device into and through an oscillating distributing shoot which delivers the substance evenly. According to the present invention, the oscillating distributing shoot A through which the fuel falls from the outlet mouth C of the delivery device, is mounted in and carried by a revolving body part E, which is supported by a structure at the top of the gas producer, this structure having a bottom opening through which the oscillating distributing shoot A projects

Fig. 1.

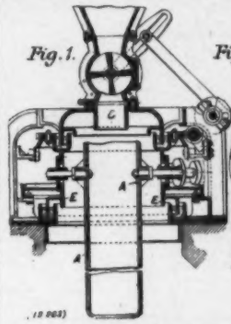
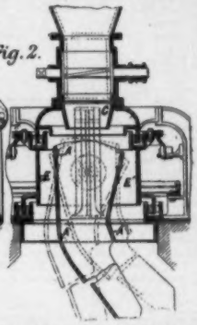


Fig. 2.



into the body of the gas producer. The open lower part of the distributing shoot A inclines towards one side and the arc of oscillation is such as to deliver the substance from the centre of the circular gas producer to the circular wall of the same, and thus, as the distributing shoot revolves, the substance will be delivered fairly evenly over the whole of the gas producer. Mechanism is provided for automatically revolving the body part E together with the distributing shoot A and for simultaneously imparting the necessary oscillating movements to the latter. Moreover, gastight traps containing water, oil or sand, are provided at the junction of the top and bottom of the revolving body part and the structure so as to prevent the escape of gases from the gas producer. (*Sealed.*)

113,238. F. J. Bell, Birmingham. Internal-Combustion Engines. (3 *Figs.*) September 19, 1917.—The invention comprises improvements in radiators for use with internal-combustion engines of the kind in which the water is passed through a series of tubes connecting a pair of tanks on the thermo-siphon principle with a tube passing concentrically through each water tube, leaving an annular water space only between them, said inner tubes extending through the tanks and being for the

passage of cooling air current therethrough. According to this invention, there is employed in combination a pair of water tanks 1, 2, a series of water tubes 3 connecting said tanks, an air tube 4 disposed concentrically within each of said water tubes passing right across said tanks, the lower ends of said air tubes being forwardly bent so as to present their lower and open ends at the front of the vehicle, and a projecting shield 5 above the upper ends of said tubes. (*Accepted February* 20, 1918.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

114,060. C. Tunstall, Shipley, and The Scott Engineering Company, Limited, Saltaire, Shipley. Lathes. (6 *Figs.*) April 20, 1917.—The invention relates to improvements in lathes. According to the invention, a slide is moved

Fig. 1.

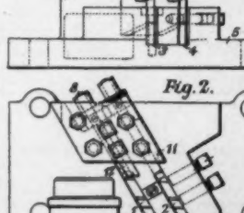


Fig. 3.

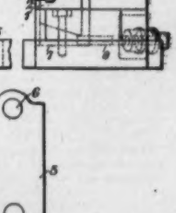
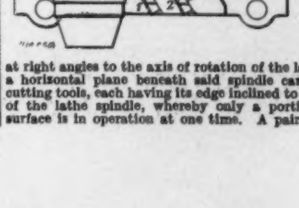


Fig. 2.

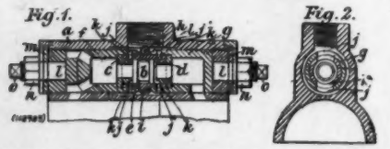


at right angles to the axis of rotation of the lathe spindle, and in a horizontal plane beneath said spindle carrying one or more cutting tools, each having its edge inclined to the axis of rotation of the lathe spindle, whereby only a portion of said cutting surface is in operation at one time. A pair of cutting tools 1,

2 are mounted in grooves 3, 4 in the baseplate 5 adapted to be secured by bolts 6 on any usual traversing slide. The tools 1, 2 can be adjusted in height by means of wedge bars 7, Fig. 3, the spindles 8 of which are threaded on their outer ends to carry knurled thumb-screws. On the baseplate 5 may be mounted a tool post 11 to carry one or more tools 12 for operating on the end of the work in normal manner. (*Accepted March* 27, 1918.)

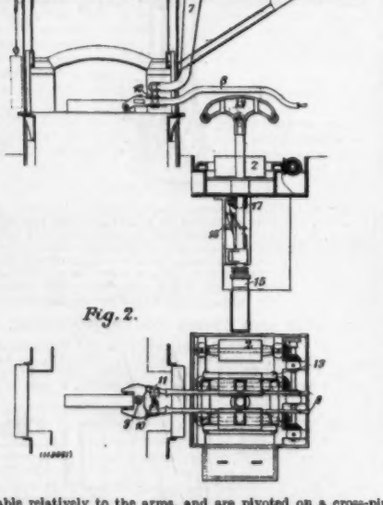
MINING, METALLURGY AND METAL-WORKING.

112,785. The Eastville Engineering and Rock Drill Company, Limited, and W. Levermore, Fishponds, Bristol. Pneumatic Percussive Tools. (3 *Figs.*) July 8, 1916.—This invention relates to rock-hammer drills of the kind adapted to be operated by compressed air and in which the valve for distributing or controlling the motive fluid is arranged between two valve seats therefor disposed within a bush having ports through which the motive fluid can pass to the distributing valve. *a* denotes the valve chest, *b* the valve, and *c*, *d* the valve seats therefor. The valve is located in the bush *e* mounted within the inner adjacent ends of the two-part sleeve *f*, *g*, and detachably secured to the valve chest so as to be incapable of angular movement by means of a bolt *h* engaging a corresponding portion of an annular projection or flange *i* provided on the bush intermediate of the ends thereof. The two-part sleeve *f*, *g*



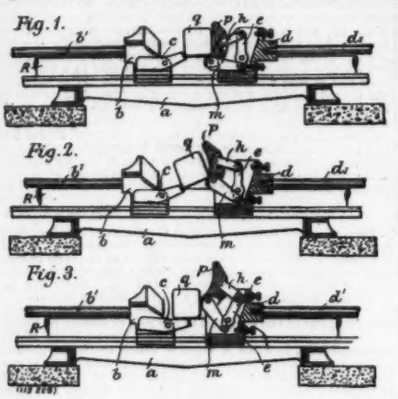
and the bush *e* are provided with elongated ports *j* and *k*, respectively, the said two-part sleeve *f*, *g*, being capable of angular adjustment relatively to the bush *e* in order to vary the area of the passage constituted by the ports *j*, *k*, according to whether it is required to allow for the passage of more or less motive fluid through the valve chamber. *l*, *l*, are the trunnions with which the two-part sleeve is formed, said trunnions being supported in bushes *m* screwed into the ends of the valve chest. Nuts *n* are provided on the trunnions for locking the two-part sleeve *f*, *g*, in position after it has been set or adjusted. The trunnions *l* are also formed with rectangular outer extremities *o* to permit of the two-part sleeve being adjusted by appropriate means, such as a spanner, for effecting the angular displacement of the said sleeve. For enabling the position of the parts *f*, *g*, to be registered with accuracy an index provided at each end of the valve chest *a*, each index being adapted to be moved over a corresponding scale or graduations formed on or attached to the valve chest. (*Sealed.*)

113,051. J. S. Atkinson and Stein and Atkinson, Limited, Westminster. Ingot-Manipulating Apparatus. (3 *Figs.*) May 24, 1917.—In the manipulation of ingots, more particularly in connection with furnaces and rolling-mills, a gripping and transporting device lifts the ingot and delivers it to a rising and falling table or support, which lowers the ingot on to transporting rollers and simultaneously turns it through an angle. The first device consists of a pair of gripping arms 8, pivoted together at 9, and carried by a depending support 7 from an overhead carriage 4. The connection between the arms 8 and the support 7 is made by blocks 11, which are longitudinally



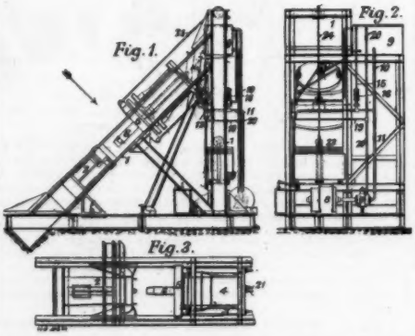
movable relatively to the arms, and are pivoted on a cross-pin carried by a pin 10 rotatably mounted in the lower end of the arm 7. In operation, the gripping jaws are positioned to embrace the ingot, and the carriage 4 is then moved to slide the blocks 11 along the arms 8. A firm grip is thus obtained, and the ingot can be lifted and transported. The table or frame work 13 is operated by a hydraulic cylinder 15, the ram of which carries a projection 17 engaging a cam groove 16. As the table is lowered, it turns through a right angle so that the ingot is brought into position for transfer to a roller-way 2. (*Sealed.*)

113,225. E. W. Davies, Dowlais. Automatic Manipulation of Ingots. (10 *Figs.*) July 13, 1917.—This invention relates to appliances for the automatic manipulation of metal ingots at rolling mills. Between two of the conveying rollers R, in connection with the roughing and cogging mill, longitudinal bedplates *a* acting as guideways are provided. Mounted so as to slide along these guideways are the two operating members. One of these consists of a crosshead *b*, operated by the piston rod *b*1, and having pivoted at each side thereof a serrated counterbalanced plate *c*. The plates *c* are enabled to dip downwards, but when the plates are released they return to their original position. The other operating member comprises a recessed cross head *d*, operated by a piston rod *d*1. Pivoted within the recessed portion of the crosshead *d* is the tilting arm *e*. Pivoted to the upper end of the tilting arm *e* is a link *h*, which is pivoted to the turning clutch *p*. Pivoted to the lower end of the arm *e* is a link *m*, which in turn is pivoted to the lower end of the turning clutch *p*. *q* shows an ingot which it is desired to turn. The use of this form of the apparatus will be easily understood. The ingot *q* travelling on the rollers R is brought into position in the ordinary way between the clutching members



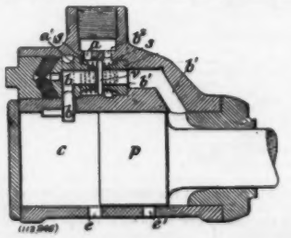
of the turning mechanism. The parts are now in the position shown at Fig. 1. On continuation of the pressure the ingot *q* is tilted up into position shown at Fig. 2, and on further continuing the pressure it falls over on the top of the plate *c*, the turning clutch *p* rising into the position shown at Fig. 3. On separating the crossheads *b* and *d*, the counterbalanced plates *c* and the parts of the turning clutch resume their original positions. (*Accepted February* 20, 1918.)

113,053. J. S. Atkinson, and Stein and Atkinson, Limited, Westminster. Stripping Ingots. (3 *Figs.*) June 6, 1917.—Relates to fluid-pressure apparatus for stripping ingots and consists in moving the stripping plunger up to the ingot by one or more pilot cylinders, and then stripping the ingot by the combined action of the pilot and main cylinders. Figs. 1, 2 and 3 show an apparatus in which the mould 2 is supported on a framework 1, which also supports the working parts. The suction end of a pump 7, driven by an electromotor 8, is in communication, through a pipe 10, with a tank 9 containing a fluid, preferably oil or other thick fluid. The pump delivers this fluid under pressure by a pipe 11 to a distributing valve 12



controlled by a hand lever. A safety valve 16 communicates with the tank by a pipe 15, and the overflow from the valve 12 returns by pipes 19, 20, to the tank or the suction side of the pump. To strip an ingot, the stripping plunger 6, carried by a crosshead 5, to which all the rams are connected, is moved up to the ingot by admitting fluid to the two pilot cylinders 3, and then the stripping is effected by admitting fluid to the main cylinder 4 also. The main cylinder communicates with the tank through a pipe 21, and a non-return valve so that it is filled as its ram moves forwards with the rams of the pilot cylinders during their preparatory movement. The cylinders are all single-acting, and their rams are returned by a weight 23 hung on chains 24 attached to the crosshead 5. (*Sealed.*)

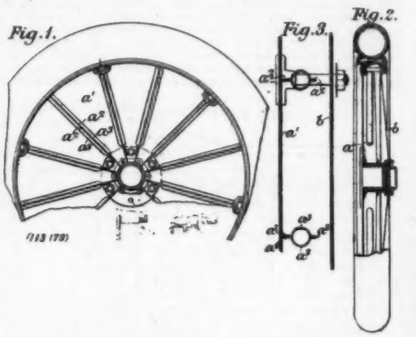
113,246. G. H. T. Rayner, Abbeydale, Sheffield, and P. Rayner, Woodseats, Sheffield. Rock Drills. (5 *Figs.*) November 5, 1917.—The object of this invention is to provide a simple and reliable rock-drill valve. The piston *p* is moved to the right under the pressure of air admitted at port *a* and passing the valve disc *v* through the channel *b* formed in the port



block a_1 and the cylinder wall, to the main cylinder *c*. The piston *p* has just passed the exhaust port *e*, thereby causing the cylinder *c* to come into direct communication with the atmosphere. A sudden reduction of pressure therefore takes place on the left hand sides of piston *p* and disc valve *v*, which latter moves to the left as soon as the total pressure on its left-hand side falls below the total pressure exerted on its right-hand side by air admitted through port b^2, plus the pressure caused by the forward movement of the piston *p* compressing the air in the right-hand end of the cylinder after the exhaust port e^1 has been passed, and forcing said air up the channel b^1. As soon as the valve moves to the left, the channel *b* is shut off from communication with the inlet *a* and the channel b^1 is in full communication with the inlet air from port b^2. Live air passes through channel b^1 to the right-hand side of piston *p* and returns the same to the left. When the piston *p* has passed the exhaust port e_1 an exactly similar cycle of operations occurs in moving the valve to the right, to that just described. The valve *v* is formed as a simple disc of substantially greater diameter than thickness. The valve is steadied in its movement from side to side by a spring or springs *s* always under some compression. The springs *s* may be provided at one or both sides of the valve. (*Accepted February* 20, 1918.)

MOTOR ROAD VEHICLES.

113,179. C. T. B. Sangster, Birmingham. Vehicle Wheels. (6 *Figs.*) April 4, 1917.—This invention relates to an all-metal disc-type wheel for motor vehicles in which one of the discs is built up from a series of wedge-shaped elements or sectors. The wheel comprises an inner disc *a*, which is permanently fixed to the centre *c* of the wheel, and an outer disc *b*, which is detachably mounted on the centre and is normally secured in position by a system of lateral bolts and other fastenings. The inner disc is built up of a number of pressed steel elements a^1, which have in plan the outline of a sector of a circle whose diameter corresponds to the diameter of the disc to be produced and the radial edges of each such sector or element



are formed with flanges a^2, so that when the several sectors are brought together around the centre of the wheel to make up a complete disc, as shown, the flanges abut and provide double-thickness webs that run radially from the centre towards the periphery and project inward from the inner face thereof. These pairs of webs may be formed with longitudinal grooves, channels or corrugations a^3 to increase their stiffness, the concaved sides of the grooves in each abutting pair of webs being opposed, or arranged so that they register and produce a hollow or tubular spokelike formation in the plane of the joint between the disc sectors, as clearly shown on an enlarged scale in Fig. 3. (*Accepted February* 20, 1918.)

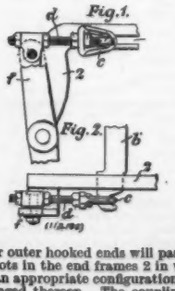
STEAM ENGINES, BOILERS, EVAPORATORS, &c.

113,219. W. R. Beldam, London. Packing. (2 *Figs.*) June 25, 1917.—This invention relates to packing for piston rods of the type known as semi-metallic packing, comprising metal elements which are in contact with the part to be packed and flexible packing material which fills the remainder of the box and spaces between the metal elements. The present invention is for a specific form of packing of this type, comprising a segmental metal ring A (or two placed side by side) to surround and fit the part to be packed and an outer wrapping B therefor

of flexible packing material, characterised by the exterior of the ring being smooth and plain and the wrapping being in one continuous piece round the ring and extending beyond it at each end, so that it can come into contact with the part to be packed at such ends, and fills the remaining space between the metal ring and the stuffing-box at the sides and ends. The ring may be bevelled on both sides, or two rings may be employed, each bevelled on one side and put together with the non-bevelled faces in contact, so that the double exterior bevel assists the flow of the packing round the single or double ring. (*Sealed.*)

TEXTILE MACHINERY.

113,192. E. Hill, Beechcliffe, Keighley. Loom Dobbies. (6 *Figs.*) April 27, 1917.—The invention relates to the type of dobby mechanism wherein reciprocating draw bars (or knivers) are made use of for actuating the catches, jack levers and consequently the heads. The reciprocating draw bars *b* are so con-



structed that their outer hooked ends will pass through any part of their guiding slots in the end frames 2 in which they operate. The hooks are of an appropriate configuration so that a coupling-piece *c* can be hinged thereon. The coupling-piece is mounted upon the outer end of a connecting rod *d* that joins said coupling-piece *c* to its operating lever *f*. (*Accepted February* 20, 1918.)